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The Effect of Three Different Types of Feedback on the Amount of Force Generated During Isometric Contraction of the Triceps Brachii Muscle

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The Effect of Three Different Types of Feedback
on the Amount of Force Generated During
Isometric Contraction of the
Triceps Brachii Muscle

by

Cindy I. Buchanan

B.S., Russell Sage College, 1973

Thesis

submitted in partial fulfillment of the requirements for the

Degree of Master of Science
Department of Physical Therapy
School of Allied Health Professions
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This thesis is dedicated to
my mother and my father who
gave me the most important
education.

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TABLE OF CONTENTS

	Page
DEDICATION	iii
ACKNOWLEDGEMENTS	iv
LIST OF TABLES	vii
LIST OF FIGURES	viii
ABSTRACT . . . . .	.ix
Chapter	
1. INTRODUCTION . . . . .	.1
STATEMENT OF THE PROBLEM . . . . .	.3
SIGNIFICANCE OF THE PROBLEM	3
HYPOTHESES . . . . .	.4
SCOPE AND LIMITATIONS	5
ASSUMPTIONS	5
DEFINITIONS	6
ORGANIZATION OF REMAINING CHAPTERS . . . . .	.7
2. REVIEW OF LITERATURE . . . . .	.8
ISOMETRIC EXERCISE . . . . .	.9
MOTIVATION AND FEEDBACK . . . . .	.12
STUDIES OF ISOMETRIC STRENGTH AND MOTIVATION	19
ELECTROMYOGRAPHIC BIOFEEDBACK . . . . .	.22
SUMMARY . . . . .	.23
3. METHODS AND PROCEDURES	25
MATERIALS . . . . .	.25
Subjects	25
Electromyographic biofeedback . . . . .	.25

Chapter	Page
Cable Tensiometer . . . . .	.27
PROCEDURES	29
Task Performance	29
METHOD OF DATA ANALYSIS . . . . .	.31
SUMMARY . . . . .	.31
4. RESULTS . . . . .	.33
CALIBRATION OF FORCE VALUES BY LINEAR REGRESSION .	33
ANALYSIS OF VARIANCE	37
5. CONCLUSIONS AND RECOMMENDATIONS . . . . .	.39
DISCUSSION	39
The sample studied	39
Feedback variables	40
RECOMMENDATIONS FOR FURTHER RESEARCH	42
SUMMARY . . . . .	.43
BIBLIOGRAPHY . . . . .	.44
APPENDICES . . . . .	.49
VITA . . . . .	.51

LIST OF TABLES

Table	Page
1. AVERAGE ISOMETRIC TENSION IN POUNDS UNDER THE INFLUENCE OF BIOFEEDBACK, KNOWLEDGE OF RESULTS, AND VERBAL CUES . . . . .	.35
2. SLOPE AND Y-INTERCEPT OF THE CABLE TENSIO METER CALIBRATION CURVES FOUND BY LINEAR REGRESSION . . .	.36
3. ANALYSIS OF VARIANCE COMPARING THE MEANS OF ISOMETRIC TENSION EXERTED UNDER THE INFLUENCE OF THREE DIFFERENT FEEDBACK VARIABLES . . . . .	.38

LIST OF FIGURES

Figure	Page
1. CYCLE OF MOTIVATED BEHAVIOR	13
2. THEORETICAL MODEL OF INTRINSIC AND EXTRINSIC FEEDBACK LOOPS	15
3. CLASSIFICATION OF FEEDBACK	17
4. MYO-TONE PORTABLE EMG FEEDBACK SYSTEM	26
5. CABLE TENSIO METER	28
6. SUBJECT SEATED IN THE TESTING POSITION	30

Abstract

THE EFFECT OF THREE DIFFERENT TYPES OF FEEDBACK ON THE AMOUNT OF FORCE GENERATED DURING ISOMETRIC CONTRACTION OF THE TRICEPS BRACHII MUSCLE

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May, 1980

This study was undertaken in order to investigate the effect of different feedback variables on isometric strength performance. The variables studied were auditory EMG biofeedback, knowledge of results, and verbal cues.

Nineteen normal adult women volunteered as subjects for the study. Each subject performed nine isometric contractions of the triceps brachii muscle against the resistance of a cable tensionometer. One of three different types of feedback was given during each contraction in order to motivate subjects to generate as much force as possible. Feedback variables were applied in random order; each variable was used three times. Peak force readings were recorded from the cable tensionometer at the end of each trial.

Force readings were converted into pounds by matching them to a calibration curve. The actual force values underwent analysis of variance to determine if one type of feedback variable was more effective in motivating subjects to put forth a maximum effort during isometric muscle contraction. Results showed that the type of variable used during task performance had no differing effect on the amount of tension generated. Thus, the null hypothesis that the application of either EMG biofeedback, knowledge of results, or verbal cueing has no differing effect on the amount of force that is exerted

during isometric contraction of the triceps brachii muscle could not be rejected.

Chapter One

Introduction

During the past decade, biofeedback has become an increasingly popular treatment technique in the health professions. A biofeedback research society has been organized, and reports, pamphlets, and books on the subject are proliferating rapidly. One author has noted that "biofeedback is now the subject of articles in "Science" and "Playboy" and is being used as treatment for insomnia, headache, irregular heart-beat, circulatory problems, backache, anxiety, strokes, epilepsy, asthma, reading disability, and high blood pressure". (Birk, 1973)

The process of feedback, that is, giving a person cues regarding his performance in an effort to shape his behavior, is an old practice. Feedback may take an indiscriminant form, such as general verbal cues, or it may give specific, concrete information, such as knowledge of results. Howsen (1976) refers to knowledge of results as a behavioral system that tells one if he has reached a desired goal. The system involves knowledge of a goal, motivation to reach the goal, a means to reach the goal, and a measure of whether or not the goal is reached. On the other hand, Howsen (1976) refers to biofeedback as a direct physiological control loop, the purpose of which is to ensure execution of motor behavior. Artificial receptors are used to convert motor output into sensory feedback. Both knowledge of results and biofeedback are exteroceptive, rather than internal forms of feedback.

In the field of physical therapy, biofeedback has been used primarily in attempts to relax both general and specific musculature, to control spasticity in complicated neurological conditions such as cerebral palsy and hemiplegia, and in the reeducation of paralyzed muscles. Gaarder and Montgomery (1977) fear that what is valuable in the methods of biofeedback may become lost in confusion and misunderstanding. In the field of physical therapy, this fear is justified; it is difficult to keep biofeedback in perspective when testing its effectiveness on already confusing disorders such as severe brain and spinal cord damage. A major contribution to physical therapy may be to test the effectiveness of biofeedback methods in a simple setting.

Although an abundance of material exists on the reeducation of paralyzed and demervated muscles, very little research exists on the use of biofeedback to increase the strength of muscles which are neurologically intact. Arps (1920) found that the amount of physical work as well as the rate of work performance of specific musculature increases with knowledge of results. Pierson and Rasch (1964) found that isometric strength scores of the biceps brachii muscle also increase with knowledge of results. These researchers did not test feedback methodologies however, but rather feedback versus the absence of feedback. Again, the effects of biofeedback as opposed to different feedback methods is an area that deserves recognition and research.

Statement of the Problem

The purpose of this study is to examine the effectiveness of auditory electromyographic biofeedback, knowledge of results, and verbal cues in coaxing healthy individuals to approach maximum force during isometric muscle contraction. The effect of these three variables on the amount of isometric muscle force an individual is able to generate will be tested.

Significance of the Problem

Several researchers have found isometric exercise to increase a muscle's ability to generate force more efficiently than isotonic exercise regimes (Hettinger and Muller, 1953; Lieberman and Asa, 1959; Rose, 1957; Ward, et al., 1964; Zohn, et al., 1964). Furthermore, in the presence of joint pathology, isotonic exercise is often contra-indicated, leaving physical therapists to rely on isometric exercise programs to maintain and increase muscle strength. The success of isometric exercise depends on the patients' efforts to exert near maximum force during muscle contraction, as well as on the duration and frequency of contractions. Downey and Darling (1971) state, "Exercise to increase strength must tax a muscle's ability to exert force by maximum or near maximum contractions". Rarick and Larsen (1958) found isometric contractions of eighty percent of maximum result in a slightly higher strength gain and less decline in strength after ceasing the exercise program than does exercising at two-thirds of maximum with less frequency. In accordance with these findings, Walters, et al. (1960) discovered that a maximum isometric

contraction method of exercise is superior to a two-thirds of maximum contraction method in strength development. Intensity of isometric contraction is of greater importance than frequency of contraction in maintaining strength according to Morehouse (1967).

He further discovered that acquired muscle strength may be maintained by exerting an isometric contraction of one-hundred percent maximum at least every two weeks.

Hellebrandt and Houtz (1956) in an experiment employing underload, optimum, and overload principles emphasize that restoration of muscle function is possible only if the limits of performance are persistently extended. In a study of progressive resistive exercise, Houtz, et al. (1946) concluded that the responsiveness of the subject to psychic stimulation is variable of dominant importance. This group further discusses the importance of the physical therapist to instill in patients the will to extend the severity of exercise whenever the objective is improvement of strength. The results of the study proposed here may provide insight into the best means of instilling this desire in patients; specifically, how to motivate patients to make genuine efforts toward approaching maximum physiological force during isometric muscle contractions.

Hypotheses

H₀: The application of either auditory EMG biofeedback, knowledge of results, or verbal cueing has no effect on the amount of force that is exerted during isometric contraction of the triceps brachii muscle by normal women.

H_a: The application of either auditory EMG biofeedback, knowledge of

results, or verbal cueing effects the amount of force that is exerted during isometric contraction of the triceps brachii muscle by normal women.

Scope and Limitations of the Study

- 1) Only women between the ages of twenty and thirty acted as subjects.
- 2) The right upper extremity of persons exhibiting right hand dominance, as self-defined, was studied.
- 3) Subjects had no history of joint and/or neuromuscular pathology in the right upper extremity, nor any neurological deficits, as self-defined. So extrapolation should not be made to patients with pathology present.
- 4) Isometric contraction of the triceps brachii muscle was examined in only one position of the right upper extremity, which was the position of maximal physiological and mechanical advantage.

Assumptions

- 1) The subjects tested are representative of the normal population.
- 2) The experimental apparatus does not impede normal isometric contraction of the triceps brachii muscle.
- 3) Prior experience with or knowledge of biofeedback does not bias subjects' efforts to approach maximum isometric muscle force throughout the testing period.
- 4) The cable tensionometer is a valid instrument for measurement of force exerted by isometric muscle contraction.

Definitions

Cue: A cue is a secondary stimulus that guides behavior. (Webster, 1968)

Verbal Cue: A verbal cue is a type of cue where the stimulus is projected through a monologue.

Feedback: Feedback is a stimulus used to manipulate a system's behavior by reinserting into the system results of it's past performance. (Weiner, 1961)

Biofeedback: Biofeedback is a special case of feedback, whereby an attempt is made to apply feedback to a biological system in an effort to alter a physiological process. The feedback is artificial in the sense that it is mediated by man-made detection, amplification and display instruments, rather than being present as an inborn feedback loop inherent within the biological system. (Birk, 1973)

Electromyographic (EMG) biofeedback: EMG biofeedback is a special case of biofeedback whereby myoelectric signals from muscle are translated into acoustic and visual signals such as buzzers and lights. This is accomplished by collecting, amplifying and displaying the electrical activity of the muscle which is concurrent with the contraction. (Basmajian, 1979)

Iometric contraction: An isometric muscle contraction is that type of contraction during which mechanical energy is not expended in muscle shortening, however an increase in tension within the muscle occurs; as the contractile element shortens, the series elastic element stretches, exerting energy against a stationary resistance, thereby developing tension. (Huddart, 1975)

Muscle Force: Muscle force is that force which muscles exert upon limbs to which they are attached. The actual force produced by individual muscles cannot be easily predicted due to the indeterminate influence of a number of physiological and mechanical factors. Therefore, muscle force is referred to as the resultant moments of force produced by all the muscles acting across a particular joint. (Miller and Nelson, 1973)

Stress: Stress is the internal resistance of a material reacting to external forces which tend to deform or strain the material. (LeVeau, 1977)

Tension: Tension is a type of static force which is the resultant of colinear forces acting in opposite directions to pull apart. (LeVeau, 1977)

Organization of Remaining Chapters

The remaining chapters of this thesis are organized as follows: Chapter two includes a summary of literature related to the topic. The topics discussed are: isometric exercise, motivation and feedback, and biofeedback. Experimental procedures and methods of data analysis are described in Chapter three. The results and statistical significance of the study are presented in Chapter four. Chapter five contains a discussion, conclusions, recommendations for further study, and a summary of the thesis.

Chapter Two

Review of Literature

The development of efficient means to increase and maintain muscle function is of prime concern to physical therapists. Isometric exercise is often prescribed to increase static strength. However, research investigating the amount of muscle tension that must be generated in order to make isometric exercise effective in increasing static muscle strength presents varying results (Baer, et al., 1955; Walters, et al., 1960; Hansen, 1961; Morehouse, 1967; Hislop, 1973). Agreement does not exist on the issue of the percent of maximum tension that muscle must generate in order for it to increase in strength.

The physiological reactions of muscle tissue to near maximal tension have been studied from the level of the muscle fiber to entire muscle systems. Unfortunately, when attempting to apply maximal tension to muscles in a clinical situation, the psychological as well as physiological factors involved in isometric muscle contraction must be investigated. The responsiveness of the subject to psychic stimulation is found to be of dominant importance during exercise whenever the ultimate objective is improvement of muscle strength (Houtz, et al., 1946). In fact, the most important element in isometric exercise performance may not be the ability to perform a near maximal contraction, but the will to perform it.

The purpose of this chapter is to present a review of literature related to this study. The chapter is divided into four sections. The sections deal with isometric exercise, motivation and feedback systems,

the effect of motivating factors on isometric muscle strength, and a review of biofeedback.

Isometric Exercise

Clinical situations often arise where muscle strengthening is needed but joint movement is contraindicated. In this situation, therapists must rely on isometric exercise techniques in order to gain muscle strength. Others may choose to utilize isometric exercise in rehabilitation programs because they have been found to be more efficient than isotonic exercises in terms of time spent exercising and rate of strengthening (Donald and Kruse, 1957; Zohn, et al., 1964; Ward, et al., 1964).

During an isometric contraction, mechanical energy is not expended in muscle shortening however an increase in tension within the muscle occurs. As the contractile element shortens, the series elastic element stretches, energy against a stationary resistance is generated, and tension develops (Huddart, 1975). When muscle tension develops, there is no limb movement (Easton, 1974). A force such as this which tends to deform an object is termed stress; stress being measured in force per square inch. In order for an isometric contraction to be effective in muscle strengthening, a sufficient amount of stress must be created. Increasing the duration, frequency, or intensity of muscle contractions during isometric exercises increases stress.

Hislop (1973) designed a study to quantitate strength increases with respect to frequency, duration and intensity of isometric contraction. She tested forearm flexion at an angle of ninety degrees in ninety-one male subjects. Her results indicated that both increased frequency and duration of contraction effect muscle strength posi-

tively. Most significantly, she found that strength gains by subjects exerting maximal efforts always exceeded gains by those exerting sub-maximal contractions. In an earlier study, Morehouse (1967) found intensity of contraction was of greater importance than frequency in maintaining muscle strength.

Hettinger and Muller (1953) studied different muscle groups in nine boys in one of the first experiments investigating the amount of tension needed to increase strength during isometric exercise. Their results indicated that the load against which contraction takes place must be greater than thirty-three percent of maximum if strengthening is to occur. Five years later, Rarick and Larsen (1958) studied isometric exercise at sixty-six and eighty percent of maximal tension. Testing the wrist musculature of adolescent male subjects, they found slightly higher strength gains and better retention in subjects who had exerted eighty percent of maximum effort. In a similar study, Walter, et al. (1960) compared the effects of isometric exercise against maximal and two-thirds maximal resistance on elbow flexion strength in fifteen students. The results indicated that full isometric contraction is superior to two-thirds maximum contraction in strength development. Cotten (1967) tested the same muscle group at twenty-five, fifty, seventy-five, and one hundred percent of maximum. He found no strength increase in subjects exercising at twenty-five percent of maximal contraction, however he did find strength gains in the other three groups.

The importance of intensity of contraction during isometric exercise in order to gain strength is well recognized. Hansen (1961) suggested that failure of subjects to increase their strength after

a five week training program was because they exerted only sixty percent of their maximum. Furthermore, Baer, et al. (1955) in studying the strengthening effects of isometric exercise and isotonic exercise at varying constant velocities suggested that improvement under isometric conditions should be greatest because more tension is developed at slower rates (the rate of isometric contraction being 0). When their results did not support this hypothesis, the researchers suggested that failure of the theory lay in the subjects' failure to exert maximal effort. Rasch and Morehouse (1957) questioned if subjects voluntarily work as hard under isometric exercising conditions as under isotonic conditions. Finding greater strength gains in those subjects exercising isotonicly, subjects exercising the same muscles isometrically were interviewed. They complained that it was frustrating to exert full strength and see nothing happen, and that furthermore the isometric exercises were boring.

Although the exact amount of tension needed to increase strength during isometric exercise is not agreed upon, it is evident that contractions must be of sufficient intensity in order to be effective in increasing strength. In order to persuade subjects to reach a sufficient intensity, boredom and frustration must be overcome. If therapists are to continue use of isometric exercise for strengthening purposes, they must set up conditions that will motivate subjects to exert sufficient tension during muscle contraction.

Motivation and Feedback

Stallings (1973) defined motivation as "regulation of the intensity and direction of behavior toward a goal". "Bringing an individual's performance to the maximum level of ability requires motivation" (Sage, 1971, p. 371). It is possible to possess a high level of ability yet perform poorly. The muscle force that one is able to generate may fluctuate based on perception, fatigue, emotion, environment, and motivation. In fact, several investigators have found isometric strength scores to change in test-retest situations (Hislop, 1963; Schenck and Forward, 1965; Hood and Forward, 1965; Kroll, 1973). In order to overcome factors inhibiting one's performance, one must be motivated. "Motivation is the energizer of our behavior" (Drowatzky, 1975).

Morgan and King (1966) describe motivated behavior as a cycle with three components (Figure 1). The three components are the motivating state, the motivated behavior, and the satisfying condition. The motivating state may be due to physiological drives, such as hunger, or psychological drives, such as achievement. Motivated behavior is action stimulated by the motivating state. The satisfying condition is the goal the individual seeks. Achievement of one's goal terminates the cycle until the motivating state is re-established.

The interaction of physiological, or primary, and psychological, or secondary, drives produces motivated behavior. Therefore, motivation is highly individualistic and motivational variables may at times be hard to identify. One method of identifying variables is to observe behavior, introduce different hypothesized motivational variables, and observe for a change in behavior. Two criteria which

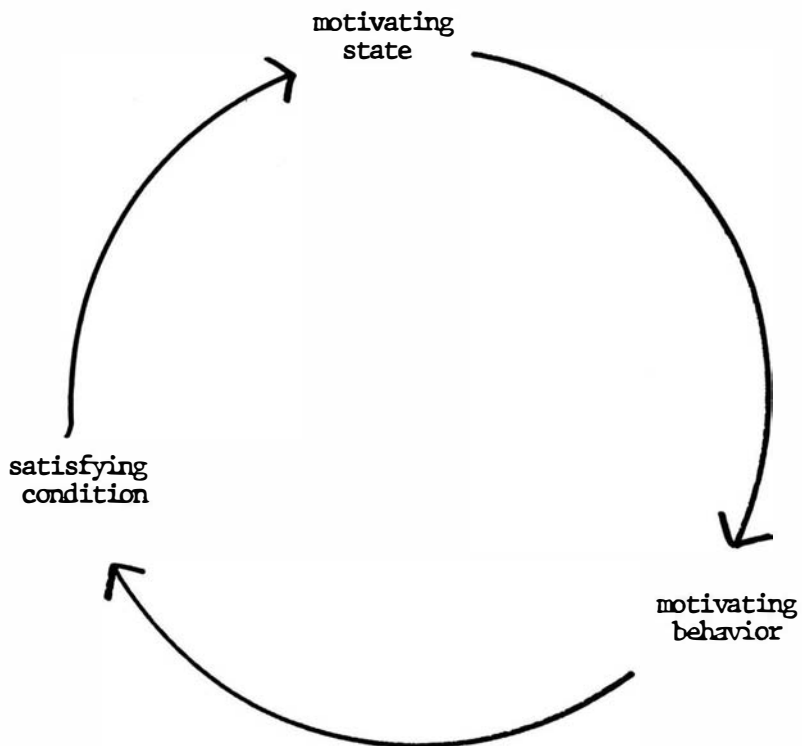


Figure 1. Cycle of Motivated Behavior
(Redrawn from Morgan and King, 1966)

may be used to identify motivational variables are: 1) they will facilitate or energize responses, and 2) changes in the variable will weaken certain responses (Brown, 1961).

According to Arnet (1969), feedback often provides motivation. Sage (1971) states that feedback is one of the most critical variables that affect motor performance. Bilodeau and Bilodeau (1961) support this contention in the following description of feedback:

"Studies of feedback...show it to be the strongest, most important variable controlling performance and learning. It has been shown repeatedly, as well as recently, that there is no improvement without (it), progressive improvement with it, and deterioration after it's withdrawal... No other independent variable offers the wide range of possibilities for getting man to repeat, or change his responses immediately or slowly, by small or large amounts."

Research consistently shows that feedback increases the rate of improvement and enhances performance (Bilodeau, 1952; Fitz and Leonard, 1957; Snode, 1958; Kinkade, 1963; Robb, 1968).

Several feedback loops influence human behavior. Feedback loops describe the effects of one's action on the stimuli affecting themselves. An organism responds to a stimulus, the response causes a new stimulus or modification of the next stimulus (Powers, 1973). "Any behavioral response to a single stimulation thus produces a sensory feedback which can act as the initiator of the second response, whose feedback initiates a third response and so on." (Hebb, 1964).

Both intrinsic and extrinsic feedback loops influence behavior (Figure 2). Intrinsic or kinesthetic feedback loops exist entirely within the behaving organism (Powers, 1973). The intrinsic loop consists of a command to execute an activity, intrinsic information

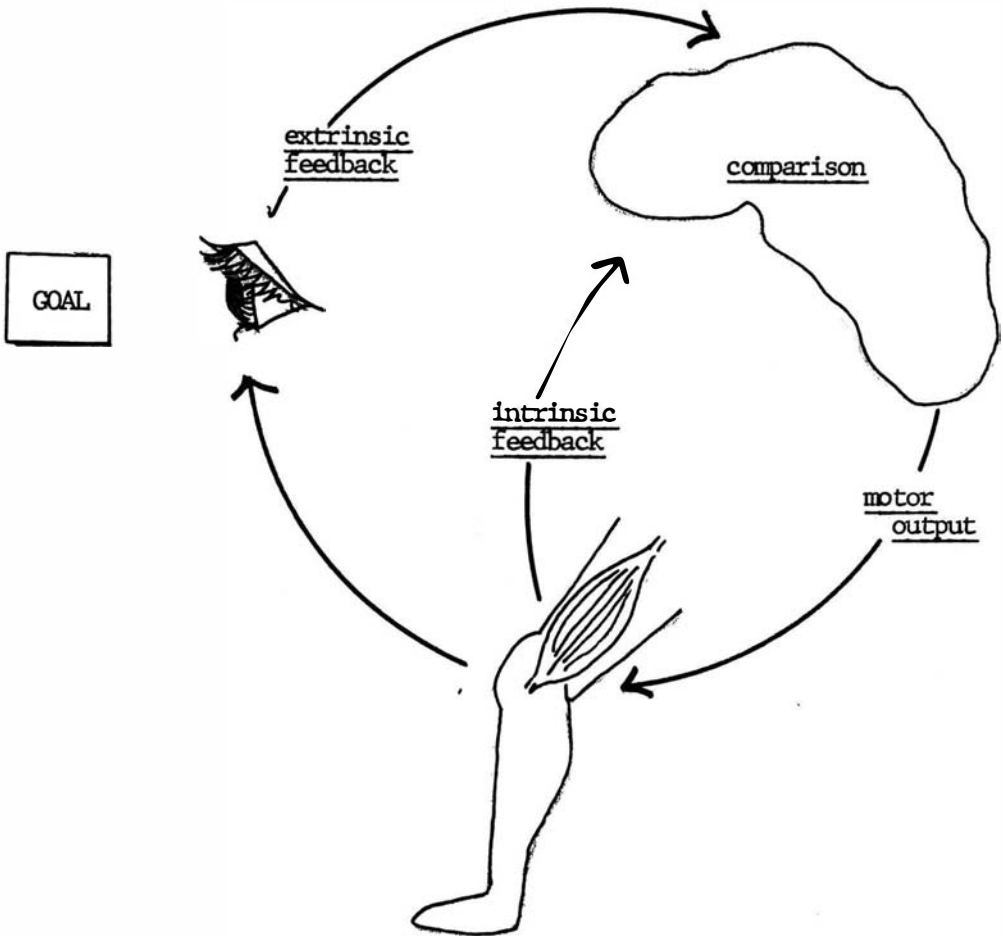


Figure 2. Theoretical Model of Intrinsic and Extrinsic Feedback Loops
(Redrawn from Velsher, 1977)

generated by the activity and comparison of the expected with the actual movement. The extrinsic loop consists of knowledge of a desired goal, motivation for reaching the goal, a means of reaching it, and feedback as to whether the goal was reached (Velsher, 1977).

Holding (1965) developed a diagram for classifying the different types of feedback (Figure 3). Under normal conditions, intrinsic feedback is naturally present in a task. This type of feedback is provided by proprioception and by the consequences of action, such as the sight of a ball being thrown. Extrinsic feedback, also termed artificial or augmented feedback, is added to a task in the form of extra information.

Holding (1965) subdivided artificial feedback into several categories. Reactive feedback is created by movement, whereas operational feedback results from the effect of performance on the environment. Dynamic feedback is concerned with changing after effects, such as the limb displacement involved after isotonic muscle contraction. Static feedback occurs with nonchanging effects, such as lack of limb displacement after an isometric contraction. Concurrent differs from terminal feedback in that it is present during an entire act rather than after the act is completed. If one were allowed to observe the dial of a hand grip dynamometer as he squeezed it, he would receive concurrent feedback. Observation of the peak force value after completing the task is an example of terminal feedback. Verbal feedback may be in the form of encouragement or praise; non-verbal in the form of buzzers, touch, etc. ... Feedback given after several responses is accumulated feedback, where as separate feedback is given after every act. Generally, the nearer the feedback category is to the left of the dia-

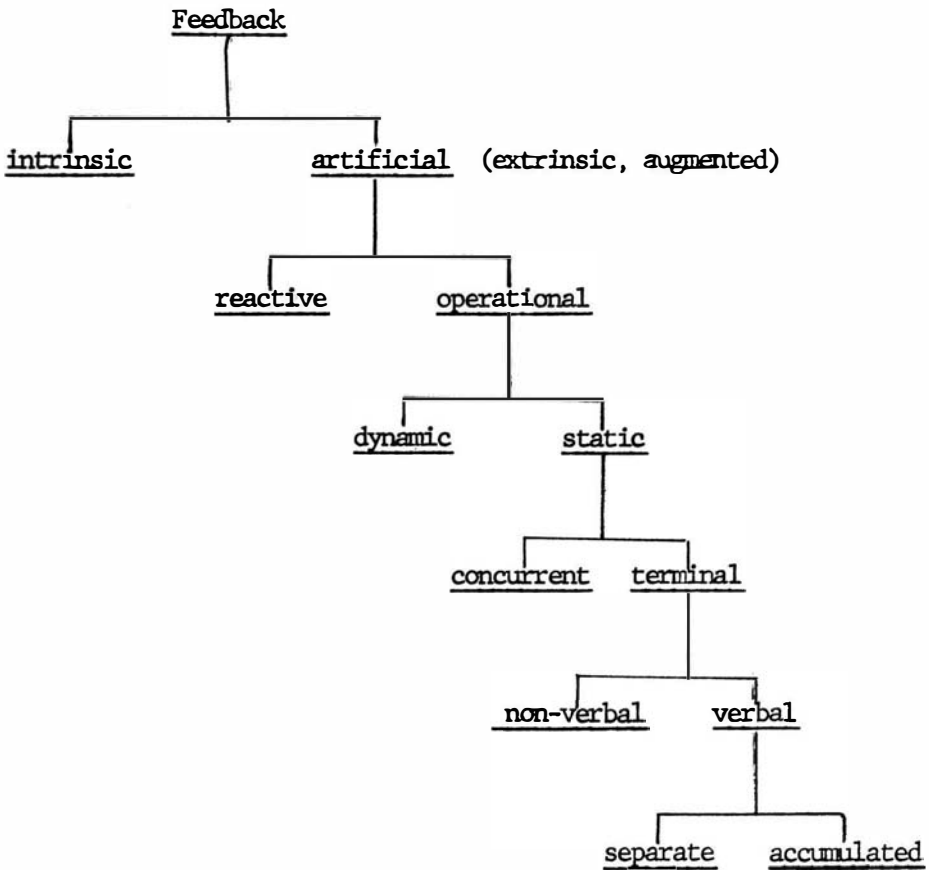


Figure 3. Classification of Feedback (Adapted from Holding, 1965)

gram, in figure 3, the more likely it is to function as a performance feedback rather than as a learning feedback.

The successful use of feedback depends on the individual, the type of skill, and the type of feedback involved (Drowatzky, 1975). Drowatzky further stated that when using feedback, one must remember that the primary purpose of artificial feedback should be to call attention to the intrinsic feedback and to aid the subject in properly using this as a guide to his performance. In essence, augmented feedback must direct attention toward the intrinsic aspects of the task in order to be effective. During isometric contraction, whether feedback is in the form of verbal praise, biofeedback, or knowledge of results, it must direct one's attention to the actual task, which is to increase muscle tension.

Isometric muscle contraction is one of the few actions that has no obvious external consequence. Therefore, augmented feedback in the form of such devices as EMG biofeedback and knowledge of results is of major importance in enhancing isometric contractions. Velsher (1977) stresses the importance of feedback during isometric exercise in the following paragraph:

"Isotonic exercise activates several intrinsic feedback loops such as muscle spindles and joint receptors. Usually it is accompanied by ... extrinsic feedback...; for example, the amount of weight lifted or the available range of movement. Isometric exercise also activates intrinsic feedback loops, but the latter are ineffective as an incentive to the performer. Action feedback during isometric performance comes from the maintenance of the static position of the joints and learning feedback is the amount of time spent in muscular contraction. Both of these have little or no incentive power to augment exercise performance."

Considering the importance of augmented feedback in isometric exercise,

little research has been done in this area.

Studies of Isometric Strength and Motivation

Research in the area of feedback generally consists of withholding certain sensory information concerning task achievement during and for varying amounts of time after performance (Ammons, 1956, p. 279). Studies in the area of feedback and isometric muscle contraction report various results, however the majority support the hypothesis that extrinsic feedback will motivate subjects to exert greater amounts of isometric force. Pierson and Rasch (1964) recorded isometric elbow flexor strength of fifteen students with and without knowledge of results. Subjects exerted two maximal isometric contractions per day for two weeks, once while viewing a load cell gauge against which the pull was exerted, and once without viewing the gauge. Isometric strength scores were reported to be significantly greater when the subject was allowed to view the gauge. In a similar study, Berger (1967) tested the grip strength of twenty-two men with and without their viewing the dynamometer dial. Dial observation is apparently a motivating factor during isometric contraction. Scores recorded while subjects observed the dial were significantly higher than those recorded when not observing the dial.

Velsher (1977) studied isometric exercise and strength gains of the quadriceps muscle in twenty-four female students without and with knowledge of results at various time intervals. After two weeks of training, she concluded that groups receiving knowledge of results of their performance developed more strength. However, she did not find any relationship between the frequency of feedback and strength gains.

In a study involving 120 men, Johnson and Nelson (1967) investigated the effect of different motivational techniques on isometric strength exerted while performing a two-handed bench press. The men trained individually for eight weeks receiving either no motivating factors, knowledge of results, knowledge of results plus an assigned goal, or knowledge of results, an assigned goal, and a placebo drug. The results showed the three motivated groups to demonstrate significantly greater strength gains than the non-motivated group. Generally strength scores increased in accordance with the number of motivators. The researchers concluded that motivation was more important than the actual training in strength gains exhibited by their subjects.

On the other hand, Ryan (1961) found that when eighty men were tested and retested seven days later, motivating conditions had no effect on grip strength. Neither those receiving verbal encouragement, knowledge of results, nor electric shock exhibited greater strength than control subjects on retests. Similarly, Jones (1962) found no relationship between motivational conditions and strength of the quadriceps and hamstrings in thirty men and women. When tested and retested three days later, in terms of muscle strength, the control group performed as well as groups receiving verbal encouragement and groups receiving knowledge of results.

Providing extrinsic feedback is only one method of altering the psychological limits of human strength. Competition, expectancy, and hypnosis have also been found to modify the expression of strength. Roush (1944) found hypnosis to have a positive effect on grip strength in twenty young men and women. Grip strength while in the hypnotic and post-hypnotic state was significantly greater than while in the wakened state.

Two studies (Rikli, 1974; Nelson and Furst, 1972) report the effect of expectancy on isometric strength and found it to be a significant variable. Rikli (1974) found that when male testers were told to expect high grip strength scores from certain subjects, they obtained significantly higher scores from these subjects. This effect did not hold true for female testers. Nelson and Furst (1972) tested the effect of expectancy on the subjects' part rather than on the testers' part. When subjects of different strengths engaged in arm wrestling matches, both believing the weaker man to be the stronger, the weaker man won the contest ten out of twelve times. These results were significant.

The hypothesis that the expression of human strength is limited by psychologically induced inhibitions was tested by Ikai and Steinhaus (1961). They used loud noises, outcries by the subjects, and hypnosis as well as drugs and alcohol to decrease subjects' inhibitions. Isometric elbow flexion was found to be significantly greater under the influence of noise, outcry, and hypnosis.

In summary, the majority of studies reported, support the thesis that isometric muscle strength is altered by psychological as well as physiological factors. "Physiological factors set the relatively fixed and outermost limits, psychological factors, the more proximate ones. In this sense it is appropriate to speak of physiological and psychological limit. Capacity is always the undetermined measure of the former. Performance is always limited by the latter." (Ikai and Steinhaus, 1961; p. 157). It is generally agreed that performance may be altered by altering the psyche, whether it be by removing or adding feedback.

Electromyographic Biofeedback

Electromyography has been used as an aid to diagnosis and prognosis for at least fifty years. However, electromyography as a therapeutic tool has been in existence for less than half that time. Electromyography is used in the form of biofeedback as a therapeutic tool. Biofeedback involves the giving of information to a person regarding one of his bodily functions through means other than his normal feelings or internal sensations (Owen, et al., 1975). In the case of EMG biofeedback, muscle activity is relayed to the individual through auditory or visual aids.

Biofeedback is a specialized type of feedback, It addresses muscular control rather than being goal oriented and may serve as a substitute for proprioception. It is coherent, continuous, and proportional to muscle response. In discussing EMG biofeedback, Basmajian (1979) states "(EMG biofeedback) provides exteroceptive cues which are accurate and instantaneous. Quantitatively, the information available is always proportional to the magnitude of muscle force. Realistically the feedback signal can substitute for inadequate proprioceptive signals and can be used to shape responses more precisely than signals generated by the clinician. This precision enables the central nervous system to re-establish appropriate sensory-motor loops under volitional control of the patient." He further states that "EMG feedback achieves its effectiveness because of its immediacy in providing the sensorium with pertinent information. ...".

The use of biofeedback in neuromuscular re-education is multifaceted. Owen, et al. (1975) reviewed the use of biofeedback in the treatment of spinal cord injury, peripheral nerve injury, Bell's Palsy,

Cerebral Palsy, Poliomyelitis, Torticollis, and Cerebral Vascular Accident. EMG biofeedback has also been found to be a useful aid in the treatment of tension headaches (Adler, 1974; Cox, et al., 1975) and in relaxation training (Basmajian, 1979; Mehearg and Eschette, 1975).

The majority of scientists and clinicians stress the importance of using biofeedback as a treatment aid rather than as a substitute for different treatment techniques. The mechanisms of biofeedback are not completely understood, and although success has been documented with the use of biofeedback, very few well controlled studies have been reported. "Definitive controlled (studies) comparing alternate treatment procedures remains to be done" before biofeedback may be used as a substitute for other treatment techniques. (Owen, et al., 1975).

Summary

Isometric exercise is often prescribed to increase muscle strength. Research does not agree on the percent of maximum force a muscle must generate during an isometric contraction in order for it to be effective in strengthening. It is generally agreed however that the force of contraction must be near maximum.

The ability to approach maximum force during an isometric contraction depends on psychological as well as physiological factors. One must be motivated to exert as great an effort as possible during the task. Motivational variables facilitate or energize responses.

Feedback often provides motivation and may be one of the most critical factors effecting motor performance. Feedback may be intrinsic or extrinsic. Intrinsic feedback is inherent in the task. Extrinsic

sis, or artificial feedback is added to the task as extra information. Extrinsic feedback is divided into several different categories.

Isometric muscle contraction has no obvious external consequences. Therefore, extrinsic feedback may be helpful in motivating individuals to perform to the best of their ability during isometric exercise. The majority of research agrees that persons generate a greater amount of isometric muscle force under the influence of artificial feedback.

Biofeedback is a specialized type of feedback. EMG biofeedback is instantaneous and proportional to muscle activity, and may substitute for inadequate proprioceptive signals. EMG biofeedback is used in muscle re-education and relaxation treatments, however it must be kept in mind that biofeedback is an adjunct to treatment and not a substitute for treatment.

Chapter Three

Methods and Procedures

This chapter reviews the methods and procedures used in conducting this study. First the subjects and materials used, including an EMG biofeedback device, and a cable tensiometer are described. Next the experimental procedure is outlined, and finally the method of data analysis is presented. A brief summary concludes the chapter.

Materials

Subjects

Nineteen normal females employed at Westminster-Canterbury Health Care Center volunteered as subjects. All were right handed and ranged in age from twenty to thirty years with a mean age of 24.68 years and a standard deviation of 3.06. All subjects took part in a pilot study seven to twelve days prior to data collection. The pilot study was designed exactly as the data collection study and served as a training session to decrease the effects of motor learning during the actual test session.

Normality was based on the fact that subjects had no learning, hearing, or uncorrected visual deficits as self-defined. Also, subjects had no history of fracture or dislocation of the right arm. Finally, subjects had no history of neuromuscular pathology as self defined.

Electromyographic Biofeedback

Electrical activity of the triceps brachii muscle was picked up by the Myo-Tone EMG feedback system *(figure 4). The system consists of

*Medgeneral Myo-Tone EMG Feedback, Minneapolis, Minnesota 55420

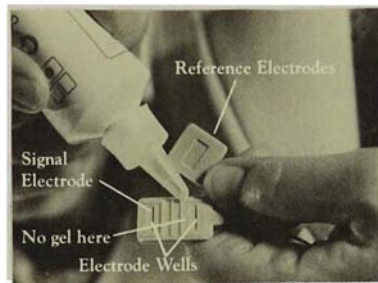
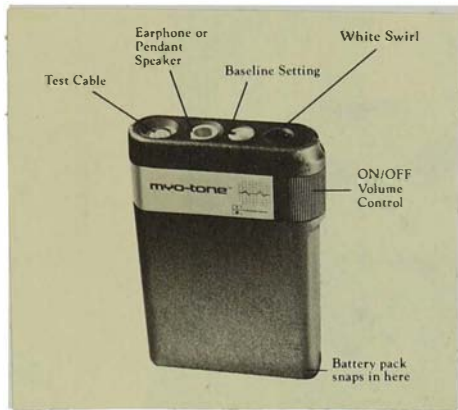


Figure 4. Myo-Tone Portable EMG Feedback System

an amplifier and processor housed in a portable case. A pair of 18mm^2 surface electrodes spaced one centimeter apart pick up electrical activity in the muscle. The EMG system transforms activity into a variable pitch audible tone heard through an accessory speaker. As muscle activity increases, the sound pitch is raised.

The myo-tone has an EMG range of 0-1500 μV peak. The input impedance of the apparatus is greater than 10^{10} ohms; the input noise is 0.7 μVrms . A bandpass filter of 100-400 Hz is also incorporated into the myo-tone to eliminate low frequency electrical noise and motion artifact.

Cable Tensiometer

A cable tensiometer* (figure 5) measured static force of the triiceps brachii muscle group. This is a mechanical device, consisting of a face dial with a needle indicator, and cable running over a riser located between two bobbins. The degree of offset is proportional to the amount of force applied to the cable and is indicated on the face dial.

The tensiometer used measures up to one hundred pounds of force in one pound increments. The instrument was calibrated each day that testing took place, by hanging weights from the cable. Calibration was performed for the range of 0-40 pounds in five pound increments. The amount of weight was hung in random order. The tensiometer was found to be linear.

* Pacific Scientific Company, Anaheim, California

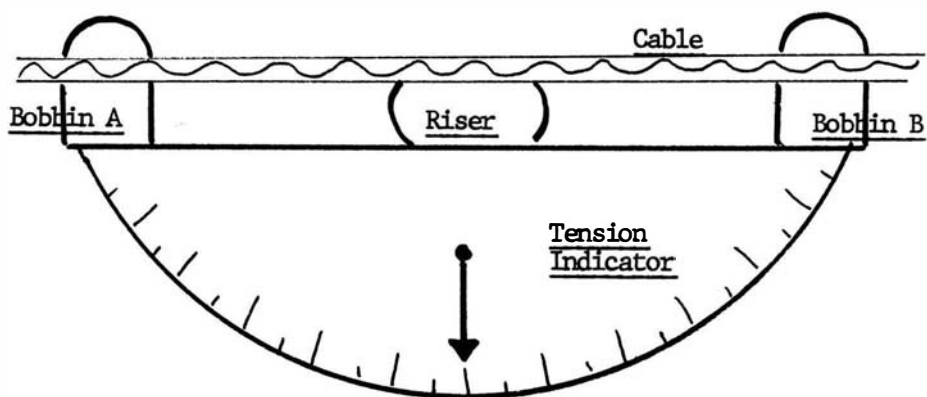


Figure 5. Cable Tensiometer

Tension on the cable between bobbins A and B creates offset of the riser. The degree of offset is registered on the face dial by the indicator.

Procedures

Prior to testing, the experimental procedures were explained and subjects signed a consent form (Appendix A). The motor point of the right triceps brachii muscle was found by electrical stimulation. The active electrode set of the biofeedback system was placed over the motor point. The ground electrode was placed over the posterior aspect of the elbow. Electrodes were applied using a conductivity gel and paper tape. After applying the electrodes, the subject was seated in the testing position.

Figure 6 depicts the testing position. Subjects sat in a straight back chair with the lower legs extended and resting on a stool near seat height. Both shoulders were strapped to the back of the chair with canvas belts. The left hand rested on the subject's lap. The right forearm was placed midway between pronation and supination, and a canvas cuff secured around the wrist at the level of the styloid process. The cuff was hooked to the cable of the tensiometer which hung perpendicularly from a steel bar mounted to the wall. The perpendicular angle between the forearm and the cable was measured with a manual goniometer. The bar was adjusted up or down along the wall in order to position the elbow at ninety degrees of flexion. Elbow angle was measured with a manual goniometer. The right shoulder was stabilized at zero degrees of flexion and abduction, and in neutral rotation by strapping the upper arm to the back of the chair.

Task Performance

Subjects performed nine isometric contractions of the triceps brachii muscle against the resistance of the hanging cable. Each



Figure 6. Subject seated in the testing position

contraction constituted one trial. During three trials, the subject viewed the tensiometer dial and was instructed to watch the needle indicator rise as she attempted to straighten her elbow with as much force as possible. During six trials, the dial was out of the subject's view. She was coaxed with verbal cues during three trials, and with auditory EMG biofeedback during another three trials to exert as much force as possible. The three sets of trials were performed in random order. Prior to each trial, instructions concerning the type of feedback used for that trial were read from index cards (Appendix B). Subjects rested at least one minute between trials.

The maximum force attained during each trial was indicated by a pointer on the tensiometer face dial. This value was recorded on paper. Values were rounded to the nearest one-half pound.

Method of Data Analysis

The peak force value of each isometric muscle contraction of the triceps brachii was read from the cable tensiometer to the nearest one-half increment. Values were matched with a calibration curve in order to determine precise force values. Each subject's calibrated values for the three trials performed under the same feedback conditions were averaged. The mean values from all subjects for each type of feedback condition were then subjected to an analysis of variance.

Summary

Nineteen healthy females employed at Westminster-Canterbury Health Care Center acted as subjects. The age range of subjects was from

twenty to thirty years. All subjects took part in a pilot study seven to twelve days prior to the testing session.

Each subject performed nine isometric contractions of the right triceps brachii muscle against the resistance of a cable tensionometer. Subjects were urged to exert maximum force during each muscle contraction. Either verbal cues, auditory EMG biofeedback, or visual cues were used to motivate the subject to exert maximum force. Peak force during the trial was read from the tensionometer. This value was recorded and used in data analysis.

Values for peak force exerted under each different type of feedback were averaged. The mean values of peak force exerted under biofeedback, verbal cues, and visual cues were subjected to analysis of variance.

Chapter Four

Results

Data collected during this study were analyzed in two steps. First, values read from the cable tensionometer were extracted from a calibration curve in order to get exact force values. Next these force values were tested for significance by analysis of variance. This chapter discusses the two steps of data analysis.

Calibration of Force Values by Linear Regression

During each day of data collection, force values were read from the cable tensionometer using known weights. Values were subjected to linear regression, using tensionometer readings as the dependent variable and known weight as the independent variable. Linear regression tests predicted the slope (a) and y-intercept (b) of a straight line formed by each set of data collected. Subsequent force values generated against the cable tensionometer were inserted into the formula:

$$y = ax + b$$

in order to predict an actual force value expressed in pounds. These actual force values, listed in Table 1, were used in analysis of variance.

Table 2 presents the slope and y-intercept values for each regression line calculated. This table also contains the F Value, and $PR > F$ values which are equivalent to the results of a t-test testing the

hypothesis that the regression parameter equals zero ($H_0 : B=0$). All $PR>F$ values are at the .0001 level, thus it is very unlikely that the regression parameter equals zero and it may be assumed that the model is valid.

Table 1

Average isometric tension in pounds under the influence of biofeedback, knowledge of results, and verbal cues.

Subject No.	Biofeed-back	Knowledge of Results	Verbal Cues
1	30.30	30.30	26.09
2	21.35	22.58	22.76
3	27.46	28.56	28.93
4	25.67	28.08	27.91
5	28.08	30.14	30.83
6	26.70	26.53	27.73
7	27.46	29.67	28.20
8	17.60	18.63	18.62
9	26.05	25.86	26.43
10	19.50	20.28	19.50
11	23.57	27.06	26.48
12	33.05	34.86	34.68
13	28.36	29.30	29.12
14	30.09	33.23	33.03
15	35.36	33.60	33.01
16	30.14	30.85	29.95
17	23.19	24.10	23.55
18	25.93	27.76	25.01
19	22.82	23.40	23.99
Mean	26.45	27.61	27.14
S.D.	4.46	4.39	4.32

Table 2

Slope and Y-intercept of cable tensionometer
calibration curves found by linear regression

Day	slope(a)	intercept(b)	F value	PR F
1	.903	2.867	2024.11	.0001
2	.950	2.214	858.69	.0001
3	.968	1.928	1022.86	.0001
4	.924	2.589	738.56	.0001
5	.849	3.089	1016.06	.0001
6	.863	2.893	1427.04	.0001
7	.884	2.911	762.15	.0001
8	.911	2.571	1077.77	.0001
9	.846	3.768	1668.39	.0001

Analysis of Variance

The null hypothesis that isometric tension does not differ under the influence of different types of feedback was tested by a one-way-classification analysis of variance in a completely randomized block design.

$$H_0. T_i = 0$$

Table 3 presents the values found by this test. An F value of .338 was calculated. Because this value is less than 1.66, the F value for eighteen and thirty-six degrees of freedom at p .10, the null hypothesis was not rejected. The alternative hypothesis, that different types of feedback effect isometric strength performance was rejected.

Table 3

Analysis of Variance comparing the means of isometric tension exerted under the influence of three different feedback variables

Source	DF	Sum of Squares	Mean Square	F value
Between	2	13.029	6.515	
Error	54	1041.767	19.292	0.338
Total	56	1054.796		

Chapter Five

Discussion and Conclusions

This chapter is organized into three sections. Section one presents a discussion based on the results of the study. The second section contains recommendations for further research. Finally, the entire study is summarized.

Discussion

One may conclude from the results of this study that neither EMG biofeedback, knowledge of results, nor verbal cues differ from one another in their effects on peak isometric force of the triceps brachii muscle of normal female subjects. In light of these results, the methods and procedures of the study and the original assumptions underlying the study must be examined.

The Sample Studied

Isometric exercise was assumed to be a boring task by this experimenter and by others (Hislop, 1963; Ikai and Stienhaus, 1969). Furthermore, this researcher assumed that minimal prior knowledge of the feedback variables employed would negate subjects' bias toward exerting more effort under the influence of any one feedback variable. On the contrary, the subjects did not appear to be bored during testing. All subjects showed an interest in the study and in doing well. The majority questioned if they had performed as well as their colleagues, and may have used this concern as an additional motivating factor. If a training program had been set-up (and strength gains rather than peak force measured) a greater degree of boredom might

have been established.

Subjects were well informed on the purpose of the study, and most voiced an opinion as to which feedback variable they felt would give better results. It was obvious that the majority of subjects were biased toward one particular variable. Had the experiment been undertaken using either patients or persons with learning disabilities as subjects, different inherent concerns and goals would probably have been present. These concerns may have enhanced subjects' motivation to do as well as possible always, thus eliminating bias towards one particular form of feedback.

The motivating effect of feedback depends on the ability of persons to perceive that type of stimulation; one would not attempt to give auditory feedback to a deaf person. It is assumed that the subjects used in this study were capable of receiving the feedback variables. However, as a person matures from the infant to the geriatric state, he goes through psychological and physiological changes. Age may have a significant effect on one's ability and willingness to receive certain types of feedback. The variables used in this study could have different effects on isometric strength performance of a different age group.

Feedback Variables

All three variables in this study produced the same effect on peak isometric force of the triceps brachii muscle. Although it was assumed from previous studies (Pierson and Rasch, 1964; Berger, 1967; Velsher, 1977) that these feedback variables did set up a motivating effect, this cannot be assessed from the results of this study. All

the variables used may have had the same motivating effect or no motivating effect. Incorporating a control variable into the study would either support or contradict this assumption. The absence of a control group, in retrospect, may be the weakest aspect of this study.

Because these three variables had apparently the same effects on the amount of isometric force generated, it must not be assumed that all available feedback variables will follow this pattern. Other feedback methods, such as goal setting, mild shock, or visual EMG biofeedback may alter ones psyche to a different degree and thus alter the results of the study. Furthermore, variables used without the presence of the experimenter may offer different results. the simple presence and mood of the experimenter is a variable which was not controlled in this study. Neither were variables due to environmental distractions controlled. Blindfolding the subjects during testing may have reduced the effects of these variables.

Maximum Isometric Contraction

It was assumed during this study that subjects would not reach maximum physiological muscle force during isometric contraction of the triceps brachii. If this assumption is false, feedback variables would of course have no effect on force generation once peak isometric force had been reached. It may indeed be that it was physiological rather than psychological factors that limited subjects' isometric force output. This assumption must be confirmed before making further conclusions regarding the use and effects of external feedback on isometric muscle force in healthy persons.

Recommendations for Further Research

In order to further study of the effect of feedback variables on isometric strength performance, the following modifications in this study are suggested:

- 1) Subjects should be asked to exert maximum isometric force without feedback in order to establish a control.
- 2) Strength gains after an established isometric training program should be tested rather than peak isometric force.
- 3) Persons from a different age group should act as subjects, particularly persons from the pediatric and geriatric populations.
- 4) Different feedback variables rather than those used in this study should be compared.

The motivating effect of feedback variables on isometric force may be investigated in a clinical setting as follows:

- 1) Persons with diagnosed learning disabilities could act as subjects.
- 2) Persons with similar orthopedic or neurologic disorders could act as subjects.

Summary

This study was undertaken in order to investigate the effect of different feedback variables on isometric strength performance. The variables studied were auditory EMG biofeedback, knowledge of results, and verbal cues.

Nineteen normal adult women volunteered as subjects for the study. Each subject performed nine isometric contractions of the triceps brachii muscle against the resistance of a cable tensionometer. One of three different types of feedback was given during each contraction in order to motivate subjects to generate as much force as possible. Feedback variables were applied in random order; each variable was used three times. Peak force readings were recorded from the cable tensionometer at the end of each trial.

Force readings were converted into pounds by matching them to a calibration curve. The actual force values underwent analysis of variance to determine if one type of feedback variable was more effective in motivating subjects to put forth a maximum effort during isometric muscle contraction. Results showed that the type of variable used during task performance had no differing effect on the amount of tension generated. Thus the null hypothesis that the application of either EMG biofeedback, knowledge of results, or verbal cueing has no differing effect on the amount of force that is exerted during isometric contraction of the triceps brachii muscle could not be rejected.

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APPENDIX A

Department of Physical Therapy
School of Allied Health Professions
Medical College of Virginia

Consent Form

Permission is granted to Cindy I. Buchanan, graduate student in Physical Therapy, to measure and record the amount of muscle force that I am able to produce during isometric contraction of the elbow extensor muscles. The purpose of this study and the experimental procedures have been explained to me. I understand that the data collected during this study may be published, however my identity will not be made known from the data gathered. I understand that I may withdraw at any time from this study.

Date

Signature of subject

Witness

APPENDIX B

INSTRUCTIONS TO SUBJECTS

Biofeedback: During this trial, the biofeedback equipment will be in operation. When I say, "straighten", you should attempt to straighten your elbow with as much force as possible and strive to make the biofeedback machine sound as loudly and with as high a pitch as possible. I will tell you when to stop.

Visual cues: During this trial, you will be able to view the force scale and see exactly how much force you are exerting. When I say, "straighten", you should attempt to straighten your elbow with as much force as possible and strive to attain as high a reading as you can on the force scale. I will tell you when to stop.

Verbal cues: During this trial, I will urge you to straighten your elbow with continuous verbal cues. When I say, "straighten", you should attempt to straighten your elbow with as much force as possible. I will tell you when to stop. (After the command 'straighten', the experimenter will urge the subject to exert more force by repeating to him, "Push harder", in a loud steady voice.

VITA

