ELECTROMYOGRAPHIC ANALYSIS OF THE PECTORALIS MAJOR DURING SIX SELECTED ANTIGRAVITY CALISTHENICS

DISSERTATION

Presented to the Graduate Council of the
North Texas State University in Partial
Fulfillment of the Requirements

For the Degree of

DOCTOR OF EDUCATION

By

Russell D. Fischer, B. S., M. S.

Denton, Texas

August, 1976

Fischer, Russell Douglas, *Electromyographic Analysis of the Pectoralis Major During Six Selected Antigravity Calisthenics*. Doctor of Education (College Teaching), August, 1976, 120 pp., 3 tables, 13 illustrations, 54 titles.

The problem of this study was the analysis of the pectoralis major during six antigravity exercises using electromyographic techniques. Thirty male subjects were used for the investigation from physical education classes at North Texas State University during the spring of 1976. The research design of the study was a 2 x 6 split-plot factorial with repeated measures. The dimensions of the design were the two segments of the pectoralis major and the six selected exercises.

Procedures for the use of the electromyographic technique included proper skin preparation at the bipolar electrode sites over the defined sternal and clavicular motor points. The effects of fatigue were controlled with the use of five-minute rest periods between exercises and the use of only one trial for each subject per exercise. Exercises were randomly selected for each subject to control for a possible order effect. Each of the six exercises was performed by a cadance established by the investigator as a control for speed of movement and duration of the exercise. Instrumentation of the study was provided by the use of integrators connected

to digital displays which established a numerical score which was representative of muscular activity and, thus, was the independent variable used throughout the investigation.

Results of a two-way analysis of variance revealed significant differences to exist among the exercises, the segments of the pectoralis major and the interaction of the two main effects. Duncan's multiple comparison test used on the combined means of the segments revealed that the dip created the most muscular activity. The results of Duncan's test after a one-way analysis of variance was performed on the clavicular segment suggested the dip as creating the most activity. The pull-up did not display a significant difference in the sternal pectoralis major compared to the other exercises. A taxonomy was established as follows: the dip, the two push-ups, pull-up and chin-up, and the sit-down push-up.

During the development of the investigation, several problem areas were observed that lend themselves to further investigation. Other calisthenics and progressive resistance exercises for the pectoralis major and other muscles need to be analyzed. The sport skills that utilize the pectoralis major have not been exhaustively researched. Also, the time element for rest periods needs to be investigated for validating electromyographic procedures.

TABLE OF CONTENTS

Chapter | Page

LIST OF TABLES

LIST OF ILLUSTRATIONS

CHAPTER I

INTRODUCTION

Few would question the need for a scientifically developed taxonomy of developmental exercises. Physical educators and physical therapists are in need of information relative to the order effect of prescribing exercises for the purpose of physical development and rehabilitation. Face validity rather than scientific evidence is the present basis for most progressive exercise prescriptions. Until recently, no research has been conducted for the purpose of developing a taxonomy of exercises for muscle groups.

A progression of exercises for the rectus abdominus was established by Gutin and Lipetz (10) in 1971. These investigators realized at that time that not all people could adequately perform developmental exercises for the rectus abdominus. Sensing the importance for a continuum of exercises from low to high activity levels and a further need for classification of the performance of such exercises, these investigators established such a progression and classified which exercises in fact created the most activity in the rectus abdominus.

The investigation by Gutin and Lipetz created a significant change in the performance of exercises for the rectus abdominus; however, similar investigations using other muscles and muscle groups have not ensued. The pectoralis major, a widely used muscle in developmental exercises, has not been studied extensively, especially in terms of taxonomy of difficulty. An analysis of this muscle would remove some of the myths and assumptions that have surrounded muscular development of the pectoralis major.

In recognition of the need to establish and classify exercises for the development of the pectoralis major, this investigation has assumed that purpose. The pectoralis is one of the larger muscles of the anterior trunk wall and has a great deal to do with the mobility of the upper arm. Investigations of the pectoralis major are needed because of its role in upper arm mobility.

Previous electromyographic studies of the pectoralis major have been categorized into three areas. The first category of concentration is the analysis of selected sports skills that utilize the pectoralis major (1, 11, 14). Investigators have analyzed duration, occurrence, and exertion of the pectoralis major. These studies also compared the pectoralis involvement and coordination between good and poor performers. The second category of electromyographic studies has defined the basic upper arm movements which involve the pectoralis major as a prime mover (5, 13, 20). The third and most deficient category is the comparative studies of exercises purported to develop the pectoralis major. Given the evidence of past research, Hinson (12) conducted one of the few studies that have dealt with exercises for the development of the pectoralis major.

The pectoralis major is readily active in several sports skills involving upper arm movement, but the research in the sports skills area has been by no means exhaustive. It would seem that the third area, development of the pectoralis major, would be very important to several sports skills. The dearth of research in the area of developmental exercises for the pectoralis major has been the impetus for this study, therefore, an analysis of the pectoralis major during selected exercises has been indicated.

Statement of the Problem

The problem of this study was the analysis of the pectoralis major comparing six selected antigravity exercises using electromyographic techniques.

Purposes of the Study

The purposes of this study were to answer the following questions.

1. Is there any mean group difference of pectoralis major activity attributable to the selected exercises?

2. Is there any mean group difference attributable to the observed portions of the pectoralis major?

3. Is there any mean group difference attributable to interaction of exercise types and observed portions of the pectoralis major?

4. Is it possible to establish a progression of the observed exercises from low to high activity levels?

Hypotheses

The research problem undertaken in this study required the advancement of six major hypotheses. All hypotheses were tested at the .05 level of significance.

1. There will be a significant difference in the pectoralis major activity among the selected exercises.

2. The clavicular portion of the pectoralis major will produce a significantly greater activity level than the sternal portion in the exercises under investigation.

3. There will be significant interaction effects between the exercises and portions of the pectoralis major.

4. The dip will produce a significantly greater activity level within the clavicular portion of the pectoralis major than any of the exercises under investigation.

5. The pull-up will produce a significantly greater activity level within the sternal portion of the pectoralis major than any of the exercises under investigation.

6. There will be an order effect in terms of pectoralis major activity among the selected exercises.

Background and Significance

Man for centuries has studied that element of his physical being that creates movement, the muscle. As early as 1700 Duverny (16, p. 2) conducted the classical experiment of mechanical stimulation of a frog leg. Galvani (16, p. 4) in 1794 was the first to suggest electrical stimulation for producing a muscle contraction and his work was further verified in 1838 (16, p. 5) when it was discovered that electrical current did originate in the muscle for contraction purposes. Prior to Duchenne's work, all muscle stimulation was done directly to the muscle tissue. Duchenne (16, p. 6) in 1833 was the first to stimulate a muscle through the surface of the skin. He also suggested that some areas seem to be more likely to elicit a response.

Electrodiagnosis became clinically practical when Proebster (16, p. 17) in 1928 noted the irregular firing patterns of denervated muscle of a small boy. Proebster has been called the "father of clinical electromyography" because of his significant clinical observations. A significant step in electromyography was taken when Bayer (16, p. 18) in 1950 revealed that muscle potential increases with the strength of the contraction. Many authorities, including Miles (17, 25) had earlier suggested the possibility of greater electrical activity with increased contraction, but did not have the sophisticated equipment of Bayer's work. Bigland and Lippold (6) observed the relationship among force, velocity and integrated electrical activity. These investigators concluded when muscle lengthening or shortening was held constant, the electrical activity was proportional to tension. When tension or resistance was held constant with increases in velocity, there was an increase in electrical activity. Therefore, tension, velocity, and electrical activity have been found to be interdependent.

The technique of electromyography historically has been intertwined with anatomy and physiology. Kinesiologists have used this technique for purposes other than those of a clinical nature. O'Connell and Gardner (18) have suggested areas where electromyography may be a research tool for kinesiologists within the field of physical education. First, these investigators concluded that electromyography would be of value in describing movement in muscles that were used. Secondly, the duration of muscular contraction during a particular sport skill may be analyzed. The third application of electromyography has been to examine the exertion certain muscles have in terms of movement. Therefore, muscles can be electromyographically analyzed in sports skills in terms of occurrence, duration and effort.

Several studies have been conducted to describe upper arm movements with the electromyographic technique. Slaughter (23) examined the triceps and biceps involvement in the sagittal plane. Slaughter concluded that both heads of the biceps aid movement of arm extension and forearm flexion. One of the muscles that has been identified, and has a profound effect on upper arm movement is the pectoralis major. Wells (27, p. 184) has defined the pectoralis major as a two-headed muscle in which the clavicular portion originates on the medial two-thirds of the clavicle. The sternal portion attaches to the sternum and upper six ribs. The clavicular and sternal portions are inserted into the lateral surface of the humerus by a common tendon about two to three inches wide. The fibers of the pectoralis major are twisted (27, p. 186) in such a way that the upper clavicular fibers are attached to the lower part of the humeral insertion; while the sternal portion lies superior to the clavicular fibers. Wells describes the sternal portion as active only in downward and forward movements (27, p. 186).

Sigerseth and McCloy (21) investigated several shoulder girdle muscles and the findings concurred with the results of Inman and others (13). In terms of the pectoralis major, the movements have been identified as either clavicular or sternal in nature. Sigerseth and McCloy concluded that the clavicular portion was involved with initiating upper arm extension in the sagittal plane and upper arm adduction in the horizontal plane. No conclusions were made on the sternal fiber's function.

Scheving and Pauly (20) agreed with the conclusions of Sigerseth and McCloy. Scheving and Pauly suggested that medial rotation causes electrical activity in the clavicular portion when a resistance accompanied the movement. When no resistance accompanied medial rotation, there was no activity in the clavicular fibers of the pectoralis major. These researchers further concluded that adduction is primarily a function of the latissimus dorsi and the pectoralis major.

Bearn (5) analyzed static loading of the upper limb. The muscles observed were the trapezius, deltoid, bicept, triceps and clavicular fibers of the pectoralis major. Forty-six male subjects were asked to stand relaxed, have ten pounds of weight added to their arm, and progressively increased the load to twenty-five pounds, inducing fatigue. In an unloaded state the clavicular fibers showed no activity. When ten pounds were added, there was initial activity and then silence. While twenty-five pounds were added, initial activity and then silence or slight activity was noted. Therefore, Bearn concluded that the clavicular head had some participation in prevention of dislocation of the humerus when initially loaded.

Basmajian (3, p. 163) supported Bearn's analysis of movements of the humerus. Basmajian also observed that the pectoralis is active in forceful inspiration. While breathing, rate, and depth were normal, no activity of the pectoralis major was observed.

The movements attributed to pectoralis major contraction have been well defined. Unfortunately, the analysis of the pectoralis major in terms of occurrence, duration, and effort have not been as well defined in sports skills.

Rice (19) observed some specific muscles involved in two forms of the lacrosse cradle. Little difference in lower and upper arms activity was observed in the vertical carry. The horizontal carry elicited more activity in the upper arm then in the lower arm.

Slater-Hammel (22) observed muscles of the shoulder girdle in four subjects while performing the golf swing. Only the propulsive phase of the golf swing was analyzed. All subjects were skilled and right-handed. The right pectoralis was observed to have a very active role in swinging the golf club. This was contradictory to the then current concept that the right arm was merely a guide for the golf swing.

The shot put was analyzed by Hermann (11). Hermann's study included the pectoralis major, deltoid, teres major, and triceps muscles. Six subjects were used and were rated as good, average or poor performers. Four electromyographic recordings were taken on each subject. Hermann concluded that a pattern of gradual increase in acceleration across the circle with rapid acceleration during final shoulder and arm thrust was most beneficial to performance. Secondly, he concluded that the clavicular portion of the pectoralis major along with the triceps, and deltoid contribute the greatest force for the shot put.

Kitzman (14) used electromyography to analyze professional and freshmen subjects in the performance of the bat swing in baseball. The four subjects were analyzed as to the activity in the triceps, latissimus dorsi and clavicular pectoralis major. It was observed that the professional performers' action potential peaked earlier than the freshmen. It was also observed that the left pectoralis major was active in the positioning phase of the bat prior to the propulsive swing.

Shoulder muscle activity during supportive skills on the uneven parallel bars was observed by Landa (15). Four college gymnasts purported to be good gymnasts were used as subjects. The right pectoralis major, anterior-medial-posterior deltoid, bicep, trapezius I and II and the latissimus dorsi were monitored. Landa concluded that the latissimus dorsi contributed the most activity for the skills tested. It is important to note that the skills were of a supportive nature.

Anderson (1) observed the ballistic movement of the tennis forehand drive. The muscles under investigation were the anterior deltoid, biceps, brachialis, pectoralis major, long and lateral head of the triceps and the coracobrachialis. Nine subjects were judged to be highly skilled, average or beginner. Anderson concluded there was a great variation between subjects, and that the consistency of muscle activity was greater in both the highly skilled and average player than the beginner.

Hinson (12) in 1969 contrasted four push-up styles for women. The let-down was one of the exercises where the subjects from extended position lowered themselves to the floor. Three other exercises, the knee push-up, the bench push-up, and the full push-up were contrasted with the let-down in terms of activity levels. Two groups of five women each participated in the experiment. The first group could do ten full push-ups. The second group could do only knee push-ups. The triceps, deltoid, pectoralis major, trapezius, serratus anterior, rectus abdominus and external obliques were the muscles under investigation. Hinson concluded that the full push-up created the most activity in the pectoralis major followed by the bench push-up, knee push-up and the let-down. Hinson also noted a lack of efficiency and coordination of muscles in the lower strength group. The let-down as suggested by Hinson, is a valid exercise for shoulder development if a subject is unable to do a knee push-up.

Whether muscular development is for improvement of sports skills or rehabilitation purposes, it would seem that a progression of exercises is needed for these objectives. Muscular development, strength or endurance, is needed for rehabilitation and improvement of performance. Gutin and Lipetz's study analyzed several abdominal exercises to establish a progression from low to high activity levels. Because of the importance of the pectoralis major in upper arm movements, exercises purported to develop the pectoralis major should be studied to establish differing intensities. Possibly, importance of progressive exercises is best stated by Gutin and Lipetz (10, p. 262): "In development of muscular strength and endurance it often is necessary to increase the intensity of contraction in order to move beyond a plateau..."

Definition of Terms

The terms used in this study are defined as follows:

1. Chin-up.--"occurred when a subject grasped a horizontal bar or ladder with the palms supinated. From a hanging position on the bar he pulled up until his chin was over the bar and then returned to the starting position" (26, p. 117).

2. Dip.--"was performed with the body between parallel bars in a position such that the upper arm was parallel to the bars. The subject pushed up until the arms were extended and then lowered again" (8, p. 94).

3. Electromyography.--"was defined as the study of electrical potentials produced by muscle" (3, p. 5).

4. Muscular Development.--was defined as the increase of efficiency of a muscle whether it has been an increase in strength or endurance.

5. Pull-up.--"was executed with the hands pronated, gripping the bar with the arms fully extended and

pulling up so that the chin cleared the bar. The arms were then fully extended to the starting position" (2, p. 141).

6. Push-up.--"was performed with the subject lying in a prone position with his hands under his shoulders and his fingers pointed forward. The subject then pushed up to a fully extended position with his back straight, and subsequently lowered himself to the starting position" (9, p. 24).

7. Sit-down Push-up.--"was performed with the legs elevated about twelve inches with the hands placed upon a bench behind the subject's back. The subject pushed up from the sitting position until the arms were fully extended and then lowered himself to the starting position" (24, p. 52).

8. Wide Push-up--was performed with hands placed one and one-half shoulder widths apart. The subject then pushed up to a fully extended position with his back straight and subsequently lowered himself to the starting position.

Limitations of the Study

1. This study was limited to thirty male students enrolled in physical education classes at North Texas State University during the spring semester of 1976

who were able to perform the exercises under investigation.

2. This study was limited to six antigravity calisthenics.

Basic Assumptions

1. It was assumed the subjects in this investigation would cooperate on the test items.

2. It was assumed that electromyography was a valid technique to determine relative intensities of muscular contraction.

3. It was assumed that surface electrodes detected the total muscular activity.

Procedures

Selection of the Sample

An incidental sample of thirty volunteer subjects were selected from the male population of students enrolled in physical education classes at North Texas State University during the Spring of 1976. Subjects were screened to determine if they were able to do the exercises under investigation. Those unable to properly perform the exercises were dismissed from the study and new selections were made until thirty subjects were available for investigation.

Research Design

The research model for this investigation was a two-way factorial design with repeated measures. The two main effects in the experiment were the study of different portions of the pectoralis major and the six selected exercises commonly used to develop the pectoralis major. Since all subjects were required to perform each of the six exercises, the design was termed as one with repeated measures.

Testing Procedures

Subjects reported to the North Texas State Human Performance Laboratory at pre-assigned times to be weighed, measured for height, and have their ages recorded. These date were used to describe the sample. Range, mean, and standard deviation of height, weight, and age are reported in Chapter III.

Subjects reported to the Human Performance Laboratory at Texas Woman's University to complete the testing. Transportation was provided by the investigator. Preparation of the subjects for electromyographical study required bipolar surface electrode placement at the two motor points and a ground electrode at the wrist. Hinson's (12) method of placement of electrodes was followed. The clavicular motor point was defined as inferior to the midpoint of the clavicle. The sternal motor point was defined as at the midpoint of the anterior border of the axillary space. The skin resistance was lowered to or below 5,000 ohms by shaving hair when indicated, light abrasion with sandpaper, and final cleaning with alcohol. To insure that skin resistance was below 5,000 ohms, the circuitry was checked with an ohmmeter. Basmajian (4, p.261) has cited that the use of surface electrodes express a global expression of muscle involvement. Intra-muscular electrodes are of use in monitoring single or limited numbers of motor units. The electrodes were anchored with adhesive washers and electrode paste was used to enhance conductivity.

With the electrodes in place, the lead wires were inserted into two Newport Laboratory Integrators. These integrators accumulated the signal received from the electrodes. This integrated signal was representative of muscle energy used to perform the various exercises. Two Hewlett-Packard digital displays accumulated the signals, and muscle energy was represented by the digital display. The digital output was recorded, and used as the score for that particular subject's exercise. Each subject performed each of the predetermined segmented treatments with five minutes rest between exercises. While Gutin (10) suggested two minutes rest and Hinson (12) suggested three minutes rest between exercises, results of a pilot study utilizing pectoral musculature suggested that three minutes of rest was not sufficient to avoid artifacts between exercise bouts. Two trials of the push-up, pull-up and dip revealed differences between the first and second trial in pectoralis major muscular activity. The three minute rest period did not allow sufficient time for the pectoralis major to return to baseline measures. Therefore, five minutes of rest between exercises was utilized in this study.

Each of the six exercises required both an upward and downward movement and was performed at a cadence established by the investigator. The cadence which each subject followed was: up-two-three-down-two-three. At the end of the first three counts the subject should have been at the maximal height for each exercise. When the cadence had reached the last count of three, the subject should have been in the resting or starting position. If the subject was unable to maintain this cadence, a retrial of the same exercise was given after five minutes of rest. The same rhythm was used in the screening of subjects so that the subjects were familiar with the cadence procedure. Each exercise was initiated from the lower position. The subject then pushed or pulled himself up, opposing gravity until the desired position for each exercise was attained. The subject then lowered himself to the starting position. Only one trial of each treatment was given each subject. One trial, instead of using the mean of several trials, was adopted because of the possibility of utilizing multiple trials could have caused recruitment. Recruitment of muscle tissue thus motor units, could have inflated the measured electromyographic activity.

Procedures for Treating the Data

The integrated measurement of electromyographic activity served as the dependent variable. The program STO 17 was used in conjunction with the IBM 360 computer to establish if differences did exist between exercises and between portions of the pectoralis major. The program STO 17 was a two-factor ANOVA with repeated measures. If interaction was significant, Duncan's multiple comparison test included in the above program established where differences existed. The mean score of the exercises were used to rank the exercises to establish a progression of exercises for pectoralis major development.

CHAPTER BIBLIOGRAPHY

1. Anderson, Jean P., "An Electromyographic Study of Ballistic Movement in the Tennis Forehand Drive," unpublished doctoral dissertation, Department of Health, Physical Education and Recreation, University of Minnesota, 1970.

2. Arnheim, Daniel D., David Auxter and Walter C. Crowe, Principles and Methods of Adapted Physical Education, 2nd ed., St. Louis, C. V. Mosby Co., 1973.

3. Basmajian, J. V., Muscles Alive Their Function Revealed by Electromyography, 2nd ed., Baltimore, The Williams and Wilkens Co., 1967.

4. ________________, "Electromyographic Analysis of Basic Movement Patterns," Exercise and Sport Sciences Reviews, edited by Jack H. Wilmore, New York, Academic Press, 1973.

5. Bearn, J. G., "An Electromyographic Study of the Trapezius, Deltoid, Pectoralis Major, Biceps, and Triceps," The Anatomical Record, CXL (June, 1961), 103-107.

6. Bigland, Brenda and O. C. J. Lippold, "The Relation Between Force, Velocity and Integrated Activity in the Human Muscles," Journal of Physiology, CXXIII (January, 1954), 214-224.

7. Darcus, H. D. and Nancy Slater, "Amplitude of Pronation Supination," Journal of Anatomy, LXXXVII (April, 1954), 169-184.

8. Falls, H. B., E. L. Wallis and G. A. Logan, Foundations of Conditioning, New York, Academic Press, 1970.

9. Golding, Lawrence A. and Ronald R. Bos, Scientific Foundation of Physical Fitness Programs, 2nd ed., Minneapolis, Burgess Publishing Co., 1970.

10. Gutin, Bernard and Stanley Lipetz, "An Electromyographic Investigation of the Rectus Abdominus in Abdominal Exercies," Research Quarterly, XLII (October, 1971), 256-263.

11. Hermann, George W., "An Electromyographic Study of Selected Muscles Involved in the Shot Put," Research Quarterly, XXXVIII (March, 1962), 85-93.

12. Hinson, Marilyn M., "An Electromyographic Study of the Push-up for Women," Research Quarterly, XL (May, 1969), 305-311.

13. Inman, V. T., J. B. C. Saunders, L. C. Abbott, "Observations on the Function of the Shoulder," Journal of Bone and Joint Surgery, XXVI (January, 1944), 1-30.

14. Kitzman, Eric W., "Baseball: Electromyographic Study of Batting Swing," Research Quarterly, XXXV (May, 1968), 166-178.

15. Landa, Jean, "Shoulder Muscle Activity During Selected Skills on the Uneven Parallel Bars," Research Quarterly, XLV (May, 1964), 120-127.

16. Licht, Sidney, "History of Electrodiagnosis," Electrodiagnosis and Electromyography, 3rd ed., edited by Sidney Licht, Baltimore, Waverly Press Inc., 1971.

17. Miles, Meryl, O. A. Mortensen and W. E. Sulivan, "Electromyography During Normal Voluntary Movements," Anatomical Record, XCLLL (May-August, 1947), 209-218.

18. O'Connell, A. L. and E. B. Gardner, "The Use of Electromyography in Kinesiological Research," Research Quarterly, XXXIV (May, 1963), 166-184.

19. Rice, Mary A., "An Electromyographic Study of Specific Muscles Involved in the Lacrosse Cradle," unpublished doctoral dissertation, Department of Health, Physical Education and Recreation, Temple University, 1969.

20. Scheving, Lawrence E., and John E. Pauly, "An Electromyographic Study of Some Muscles Acting on the Upper Extremity of Man," The Anatomical Record, LXXXV (December, 1959), 239-245.

21. Sigerseth, P. O. and C. H. McCloy, "Electromyographic Study of Selected Muscles Involved in Movements of Upper Arm at Scapulohumeral Joint," Research Quarterly, XXVII (December, 1956), 409-417.

22. Slater - Hammel, Arthur T., "Action Current Study of Contraction-Movement Relationships in Golf Stroke," Research Quarterly, XIX (March-December, 1948), 164-176.

23. Slaughter, Duane R., "Electromyographic Studies of Arm Movements," Research Quarterly, XXX (October, 1959), 326-337.

24. Sorani, Robert, Circuit Training, Duguque, Wm. C. Brown Co., 1966.

25. Stetson, R. H. and H. D. Bouman, "The Action-Current as Measure of Muscle Contraction," Science, LXXVII (Friday, February 24, 1933), 219-221.

26. Thompson, CLem W., Manual of Structural Kinesiology, 6th ed., St. Louis, C. V. Mosby Co., 1969.

27. Wells, Katherine F., Kinesiology, 5th ed., Philadelphia, W. B. Saunders Co., 1971.

CHAPTER II

REVIEW OF RELATED LITERATURE

The Technique of Electromyography

Electromyography has been utilized to study muscular function. The electrical energy derived from the muscle contraction has been amplified with a preamplifier. The muscle signal was then amplified again to achieve recording potential. The amplified electrical output has been recorded, and interpretation has been based upon that output. The need for an objective measure of muscle intensity has lead to the use of electromyography to obtain objective data for comparison purposes. Miles (33) suggested that the technique of electromyography provided objective evidence to broaden one's concept of muscle function. An important aspect of electromyography for consideration was the fact that the amount of electrical activity derived from the electrodes is only representative of muscular contraction. A muscle contraction and the consequent electrical activity were not the same. The correlation between muscle contraction and electrical activity within that muscle have been rather high, but a cause and effect relationship does not exist.

Lippold and others (29) implied that muscle contraction, whether induced from physiological, mechanical, neurological, emotional or fatigue state, displays an increased intensity of electrical activity. Darcus and Salter (13, p.183) suggested that no differences existed in muscular activity due to age, sex or previous physical injury. Stetson and Bouman (46) concluded that the greater the contraction, the greater electrical activity displayed. Based upon the previous studies, electromyography displayed muscular activity in terms of electrical activity no matter which type of stimulation was used; age, sex or previous injury had no effect upon electrical activity displayed, and an increase in muscular contraction was accompanied with an increase in electrical activity.

As early as 1700 Duverny (27, p.2) conducted the classical experiment of mechanical stimulation of a frog leg. The significance of the study was the demonstration that human muscle could be stimulated artificially. Galvani (27, p.4) in 1794 was the first to suggest that a muscle could be stimulated with electricity. Galvani hypothesized that electricity that originated within human beings was the element that causes muscle contraction. In 1838, Galvani's (27, p.5) theory was accepted when new research techniques provided procedures sophisticated enough to validate Galvani's hypothesis. Up to the early 1800's all stimulation whether mechanical, electrical or chemical was transmitted directly to the muscle. Duchene (27, p.6) in 1833 was the first to stimulate a muscle through the surface provided by the skin. Duchene further suggested that some areas above the muscle seem to be more likely to elicit a response.

Electrodiagnosis became clinically practical when Proebster (27, p. 17) in 1928 noted the irregular firing patterns of denervated muscle in a young boy. As a result of the capability of diagnosis with electromyography, Proebster has been called the "father of clinical electromyography." The results of Bayer's work (27, p. 18) substantiated a significant step in electromyography when he concluded that muscle potential increases with the strength of contraction. Therefore, substantiating the earlier hypothesized phenomenon that an increase of electromyographic potential was accompanied by increased muscular contraction.

Electromyography in Kinesiological Research

Bierman and Yamshon (8, p. 211) noted four conclusions that would have benefit for kinesiological research. First of all, muscles in action produce electrical potential, however, resting muscles do not produce electrical activity. Therefore, electromyography could support theories dealing with muscular occurrence in a given movement. Secondly, a muscle crossing a joint has a role in the motion of that joint. The third conclusion Bierman and Yamshon noted was the fact that one muscle may initiate a movement while another muscle completes the movement. Thus integration and coordination of muscle groups could have been analyzed with electromyography. The last conclusion reported by Bierman and Yamshon was that the position of the body, speed of movement, and degree of resistance influenced the production of electrical potentials. Therefore, electromyography could be used to compare speeds of movement, degree of resistance, and position of the body.

O'Connell and Gardner (34) suggested similar uses of electromyography in kinesiological research. The first use of electromyography in kinesiological research was occurrence of muscle activity. Whether a muscle was actually active during a particular movement could be determined by electromyography. Movement analysis suggested by O'Connell and Gardner was similar to Bierman and Yamshon's use for speed and body position. The determination of the duration of muscle contraction was another use for electromyography in kinesiological research. The determination of variable muscular effort had required increasingly sophisticated equipment and techniques. O'Connell and Gardner suggested that electromyography could be useful in determining occurrence, duration, movement analysis, and comparison of effort.

Interpretation of Electromyograms

The sophistication of interpretation of an electromyogram has been dependent on what type of questions to be answered. To measure whether a muscle was active in a movement or sports skill, the presence of an interference pattern would be adequate. For demonstration of duration of a muscular contraction, any of the pen writing devices with known paper speed would have provided the needed information. To measure intensity of muscle contraction several systems have been used. Intensity of muscle contraction has been based upon the amplitude of the interference pattern, the number of spikes in the interference pattern and the integration of electrical activity derived from the contraction.

McCloy (32) based the interpretation of contraction intensity upon the height of the interference pattern. Rating scales have been devised to interpret muscle contraction intensity. Garrison (16) described muscle contraction as strong, moderate, minimal, or none based upon the interference pattern. Hermann (19) used a scale of 0-3 based upon amplitude. A score of zero represented a deflection of less than .2 millimeters, a score of 1 represented a deflection of .2-6 millimeters, a score of 2 represented a deflection of 6-10 millimeters, and a score of 3 represented 10 or more millimeters of deflection from the baseline. Mapes (31) and Finanger (15) used the same scale in their investigations. Scales have been developed with greater differentiation for more precise evaluation. Sigerseth and McCloy (42) used a scale of

0-4 for interpretation of amplitude of an electromyogram. Basmajian and Elkus (6) based their interpretation on a scale of 0-5. Direct measurements of amplitude have been used for evaluation of electromyograms. Landa (26) measured the amplitude of the interference pattern every .2 seconds. The sum of the amplitude measurement was used for interpretation of muscular activity.

Another method of interpretation of electromyograms has been the counting of the spikes of an interference pattern. Lippold and others (28) used the frequency of the spikes for interpretive purposes. An increase of muscular contraction has been accompanied with a larger amplitude and greater frequency of spikes (33). Interpretation of muscular contraction based upon frequency of spikes has justification.

Adrian (1, p.353) stated that integrated electromyography was the most accurate form of interpretation of electromyograms. A correlation coefficient of .86 to .95 has been calculated for isometric muscle tension and integrated scores by Wilcott and Beenken (48). Males and females were used in this study with essentially a linear relationship concluded to exist between scores and tension. Partridge (25, p.1287) reported that possibly a linear relationship would exist with isotonic contraction if gravity, synergistic, and antagonistic muscles were considered. Basically, two types of integrated muscular interpretation have been used. One type of integrated system has been the use of a separate channel to inscribe a smooth curve. The area measured under the curve correlated to muscle tension. A planimeter measured the area under the curve and became the numerical interpretation of muscle contraction. Hallet (17), Harding (18), and Randall (36) used the planimeter method of integrated electromyography. Anderson (2) used the second method of integrated interpretation. This method consisted of the integrated signal connected to a digital display. The numerical figure displays have been used to represent muscular contraction. The digital display removed human error that accompanied the usage of a planimeter.

Procedures of Electromyography

The selection of procedures for electromyography lead to the type of electrodes used, interelectrode distance, skin preparation and proper rest periods between exercises. All of the above criteria lead to the development of criteria necessary for accurate evaluations.

Needle and surface electrodes have been used for electromyographical investigation. O'Connell and Gardner (34) offered two guidelines for choice of electrodes. First of all, does the investigation analyze the whole muscle or just some specific fibers within the muscle. Basmajian (3) and Adrian (1) have suggested surface electrodes for a more global evaluation of total muscle activity. Needle electrodes have been used to study muscle fibers (6). The second criteria needed for electrode selection O'Connell and Gardner reported was the amount of movement involved. Surface electrodes do not restrict amount of movement due to injury as compared to needle electrodes.

Basmajian and Elkus (6) used needle electrodes for measuring muscle fatigue. Randall (36) used surface electrodes while investigating selected muscles involved in two types of chinning. Bigland and others (9) in their classical study in establishing relationships among muscle activity, velocity of movement, and force used both needle and surface electrodes.

Two types of electrode placement have been used. A monopolar lead has one electrode directly over the motor point with a ground electrode placed on a flat bony plane of the body. A bipolar lead places two electrodes on either side of the electrodes and parallel to the muscle fibers. A ground electrode using the bipolar lead is placed in the same location as a monopolar lead.

Sigerseth and McCloy (42) used monopolar leads while studying upper arm movements. Clarke and Clarke (10) suggested that bipolar leads were more reliable and less susceptible to artifact. Lloyd (30) used bipolar leads while studying sustained isometric contractions. Hinson

(20) used a bipolar lead system while studying the pectoralis major comparing different forms of the push-up. Hinson's electrode placement for the sternal portion of the pectoralis major was over the midpoint of the anterior bordor of the axillary space. The clavicular pectoralis major placement was inferior to the midpoint of the clavicle.

Interelectrode distance varied from one centimeter to two and one-half centimeters apart. Harding (18) and Santomier (38) used two and one-half centimeters for interelectrode distance. Kamon (23) and Anderson (2) used two centimeters for interelectrode distance. Recent studies by Hinson (20) and Hallet (17) have used one centimeter for electrode distance. More involved procedures for reducing skin resistance are needed for greater distance between electrodes.

Skin preparation procedures have been suggested by several investigators for adequate conduction from the surface of the skin to electrode and to improve the validity of measurements. Randall (36) and Garrison (16) have indicated shaving the area of electrode contact to insure adhesion of the electrode. Kamon (23) and Finanger (15) have suggested abrading the skin with sandpaper to remove dried skin. Santomier (38) suggested the use of a bristle brush for the same purpose. Hallet (17) and Anderson (2) have used an alcohol wash to remove skin oils. Harding (18) and Santomier (38) have suggested the use of electrode paste to insure conductivity. Therefore, suggested procedures for skin preparation may be to shave when indicated, to abrade with sandpaper, or brush, to wash with alcohol and to use electrode paste.

The range of skin resistance has been reported from 5,000 ohms to 15,000 ohms. Hinson (20), Finanger (15), and Harding (18) established 5,000 ohms as a maximum acceptable resistance. Hermann (19) and Randall (36) established 10,000 ohms for acceptable maximum. Sigerseth (42) and Santomier (38) used 15,000 ohms as a maximum limit.

Bigland and Lippold (9) studied the gastrocnemius of males and females. They concluded that, at constant velocity, electrical activity is directly proportional to muscular tension. When tension was held constant, electrical activity increased with velocity. Therefore, speed of movement has been established as an important factor in electromyography. Hinson (20) attempted to control for speed of movement in comparing four different push-ups by establishing a five second interval to complete each exercise.

The effects of fatigue have been noted by Lippold and others (28). Lippold and others have concluded that with the emergence of fatigue, the average amplitude decreased, the longer duration occurred. Secondly, interspersed within the interference pattern were large waves of greater amplitude. The synchronous firing may have been due to recruitment of other motor units or to the increased activity of synergists. Lance and Chaffin (25) also noted change in neuromuscular function due to fatigue. They suggested that the synchronous firing of muscle tissue may be due to synchronization of motor units and/or recruitment of higher threshold motor units. Lloyd (30, p.713) concluded that the direct relationship between amplitude and muscle tension holds briefly due to fatigue inducing more spikes and greater amplitude. Therefore, rest periods between electromyographical comparisons to control for fatigue have been used with exercise bouts.

Suggested rests between exercises have been reported from two to five minutes. Santomier (38) suggested two minutes for rest. Basmajian (6) suggested four minute rest periods. Lance and Chaffin (25) used five-minute rests between exercise bouts. Rest periods have a function in electromyographical research.

Actions of the Upper Arm Produced by the Pectoralis Major

Studies of the mechanisms of shoulder movement have been done. Dempster (14) has studied several movements of the shoulder girdle. Crase (11) studied moments of force for the shoulder girdle using the pectoralis major and the anterior, medial and posterior deltoid. Wells (47, p.184) located the origin and insertion of the sternal and clavicular pectoralis major. The clavicular pectoralis major has a defined origin on the medial two-thirds of the clavicle. The sternal pectoralis major's origin has been located on sternum and cartiledge of the first six ribs. The sternal and clavicular section have a common origin on the lateral surface of the humerus just inferior to the head of the humerus. Wells suggested that the pectoralis major was active during pushing, throwing or punching activities.

Shambes and Waterland (40) studied the motor unit control of skill and postural muscles. An analysis of biceps and triceps of twenty college women suggested that skill muscles are more controllable than postural muscles. Shambes and Waterland based this conclusion upon the presence and the shape of interference patterns. If the conclusion of Shambes and Waterland was valid, the pectoralis muscle should have had a great deal of motor unit control.

The classical study by Inman, Saunders and Abbot (21, p.7) suggested that the pectoralis major at one time was a single muscle mass. Gradually, the origin of the pectoralis major migrated superiorly to produce the clavicular head. Inman and others (21, p.17) concluded that the clavicular head of the pectoralis major was active in flexion from 0 to 170 degrees elevation. No clavicular activity was present in adduction. Forward flexion was found to be attributable to the clavicular portion of the pectoralis major. The clavicular head seemed to work synchronously with the anterior deltoid during forward flexion. Inman and others (21, p. 29) concluded that the sternal pectoralis major was active in adduction and medial rotation.

McCloy (32) confirmed Inman's study and viewed some unique movements. McCloy concluded that the clavicular head was fairly active while a subject's arm was swung diagonally from a side position to an upward position. While hands were pressed together at the abdominal level, some activity was noted in the clavicular head, but much more activity was noted in the sternal head of the pectoralis major. While hands were pressed together at the level of a subject's forehead, the clavicular head was very active while the sternal portion showed almost no activity.

Sigerseth and McCloy (42) used a shoulder wheel for analysis of upper arm movement. They concluded that the clavicular head was active during the first part of upper arm extension in the sagittal plane. From shoulder level downward, the clavicular head was active in adduction in the frontal plane. Sigerseth and McCloy's final conclusion was that the clavicular head was active in adduction in the horizontal plane.

Daniels (12) suggested that from 90 degrees of flexion the sternal head was active when the arm was moved upward and outward. Downward and outward movements from 90 degrees was due to clavicular activity. Scheving and Pauly (39) concurred with other investigations concerning arm movements. Scheving and Pauly suggested that the pectoralis major was active in medial rotation only when resistance was applied. Adduction was accomplished primarily by the latissimus dorsi and the pectoralis major. Shevlin and others (41) analyzed elevation and depression from 0 to 110 degrees at three different angles in the horizontal plane. They concluded that at 0 and 45 degree positions, the sternal head was active during depression from 110 to 45 degrees of elevation. The clavicular head of the pectoralis major was active in elevation from 45 to 110 degrees at all three positions; 0, 45 and 90 degrees.

Basmajian and Elkus (6) observed male and female subjects who were hanging by their hands in pronated and supinated positions. They concluded that slight to moderate activity was noted in the pectoralis major while hanging with the hands supinated. More activity was observed in the pectoralis major while the hands were pronated.

Bearn (7) studied the static loading of the upper limb. While the limb was unloaded, no activity occurred in the pectoralis major. When a subject's limb was loaded with ten pounds, the pectoralis major displayed no activity. When twenty five pounds were added to a subject's upper limb, initial activity and eventually slight or no activity occurred. Basmajian and Bazant (5, p.1185) concluded that downward dislocation was prevented by the superior section of the capsule, by the supraspinatus and to a lesser degree by the posterior deltoid. They noted that when the humerus was forced downward, the humerus was pushed laterally because of the incline of the glenoid fossa.

Pectoralis involvement producing upper limb involvement has been documented and the prevention of dislocation of the shoulder has been discussed (7) (5). Basmajian (4, p.163) suggested the possibility of one other involement of the pectoralis major. While breathing rate and depth was considered heavy, the pectoralis major was active in forced inspiration.

Some studies have been done that have analyzed upper arm movements but have not observed the pectoralis major. Slaughter (45) observed upper arm movement, but did not analyze pectoralis major involvement. Rice (37) analyzed two types of la crosse cradles, but did not observe the pectoralis major. The upper arm movement in both of the above studies should have been obvious. The lack of consideration of pectoralis major activity would have been a limiting factor in those studies.

Pectoralis Major Activity in Sports Skills

There were two studies found dealing with pectoralis major activity in baseball. Kitzman (24) observed skilled and unskilled performers in swinging a baseball bat. The muscles that Kitzman observed were the lateral and long head of the triceps, the latissimus dorsi and the clavicular head of the pectoralis major. Kitzman derived three conclusions from his investigation. He observed that the skilled performers' action potentials peaked earlier than the non-skilled performers. Secondly, Kitzman observed the left clavicular pectoralis major was active during the start of the backswing of right-handed batters. The activity of the left pectoralis was considered to be moderate to strong for skilled batters. Kitzman's third conclusion was that strengthening the left triceps in right-handed batters would allow more force to be applied with the bat. Mapes (31) analyzed the baseball throw. The muscles involved in Mapes study were the biceps, the deltoid, the latissimus dorsi, the triceps and the sternal pectoralis major. Three college baseball players were used in the study. Mapes concluded in the check action phase that the medial and posterior deltoid, latissimus dorsi and the long head of the biceps were active. During the ballistic phase Mapes concluded that no agonist muscle was active throughout, but a segmented pattern of agonist muscular involvement did exist. The final conclusion of Mapes investigation was that slight sternal pectoralis major activity was observed during the follow-through phase of the throw.

Two investigations were conducted on the golf swing. Slater-Hammel (43) observed four right-handed male subjects who were reported to be good performers. The muscles Slater-Hammel analyzed were the lateral and long head of the triceps, long and short head of the biceps, deltoid, latissimus dorsi and the pectoralis major. Right and left sides of each subject's body was analyzed. Slater-Hammel concluded that contraction-movement relationships vary widely among subjects. Each subject's trials appeared to be coordinated in terms of analysis of the interference pattern. The acceleration of the club appeared to be the result of the right and left triceps, right latissimus dorsi, right pectoralis major and left posterior deltoid muscular involvement. Garrison (16) also examined the golf swing. Four right-handed male subjects were used who were competing amateurs. The biceps, triceps, deltoid, flexor carpi, extensor carpi, pronator teres, sternal pectoralis major and the latissimus dorsi were studied by Garrison. Garrison concluded that the right sternal pectoralis major was used beyond contact with the ball. He then concluded that no difference existed between woods and irons in the golf stroke.

Several studies have been conducted on gymnastic activities. Hallet (17) observed muscular activity in three different cross hold positions on the rings. All of the positions were with arms extended at a ninety degree angle in the frontal plane. The ideal position placed the center of gravity in the same plane as the hands. The other two positions placed the center of gravity slightly anterior and posterior for its' normal location. Eleven subjects were used who could adequately perform the iron cross in the desired positions. The muscles under investigation were the sternal pectoralis major, teres major and latissimus dorsi. Hallet concluded that the pectoralis major and teres major differed significantly from the latissimus dorsi. The latissimus dorsi displayed more electrical activity.

Kamon (23) analyzed the upper limb during static and dynamic postures of subjects on the pommel horse. The static supports were the front support and straddle support. The dynamic support consisted of continuous swing under each hand. Kamon concluded that the latissimus dorsi and the pectoralis major had a similar function in supports during the static supports. Throughout the dynamic support the sternal head of the pectoralis major was fairly active. The clavicular head was active in initiating and decelerating later movements. Kamon (22) observed the same phenomenon while the scissors exercise was performed. The sternal head was active in a supportive function. The clavicular head displayed short bursts of activity for directional changes in lateral body movement.

Landa (26) analyzed shoulder muscle activity during selected supportive skills on the uneven parallel bars. Four college gymnasts were used. The pectoralis major, deltoid, biceps, latissimus dorsi, and trapezius I and IV were observed. Landa concluded that the latissimus dorsi appeared to contribute the greatest strength for under the bar support skills.

The tennis forehand drive was observed by Slater-Hammel (44) and Anderson (2). Slater-Hammel observed both heads of the biceps, deltoid, latissimus dorsi, pectoralis major and the triceps. All male subjects that were used had several years of experience. Slater-Hammel concluded that the pectoralis major and anterior deltoid functioned to swing the arm forward. He also concluded that little difference in activity patterns existed for an individual subject, but differences between subjects was extensive. The final conclusion of Slater-Hammel was that the tennis forehand drive was not a ballistic movement. Anderson observed three different skill levels of tennis players. Beginning players, members who were seated in third, fourth, and fifth teams and regionally ranked players made up the three groups. Anderson agreed with Slater-Hammel and concluded that the tennis forehand drive was not a ballistic movement. Anderson found that among subjects and among skill levels great differences occurred. A consistent pattern of muscle activity for each individual subject in the two advanced groups was apparent. Anderson also agreed with Slater-Hammel and concluded the pectoralis major was one of the prime movers in the tennis forehand drive.

Hermann (19) analyzed selected muscles during the performance of the shot put. The muscles investigated were the pectoralis major, deltoid, teres major and triceps. Three groups were analyzed and were reported to be groups of good, average and poor performers. Six male subjects were used in the investigation. Hermann concluded that based upon the groups used, a pattern of gradual increase in acceleration across the circle provided the best performance. The largest acceleration should appear during the final shoulder and arm thrust according to Hermann. Hermann concluded that the greatest force for acceleration of muscles studied for arm thrust came from the pectoralis major, deltoid and triceps.

Finanger (15) investigated muscular function involved in the discus throw. Muscles investigated were the anterior and medial deltoid, short head of the biceps, pectoralis major, external and internal obliques, serratus anterior, teres major and latissimus dorsi. Four subjects from a college track team were used for the investigation.

Finanger found sternal pectoralis activity right after the first step of the discus throw. The pectoralis major was very active in holding the discus close to the body. The pectoralis was not active throughout the performance. From the final spin to the final plant of the foot, both the sternal and clavicular head of the pectoralis major were very active.

Comparative Exercises for Pectoralis Major Development

Santomier (38) analyzed specific muscles while performing selected isotonic weight training activities. Muscles under investigation were the pectoralis major, biceps, triceps, gastrocnemius, biceps femoris, deltoid, latissimus dorsi, rectus abdominus and rectus femoris. The activities used for the investigation were the standing press, bent-over-rowing, three-quarter squat, standing curl and bench press. Five male subjects of the college service program were used in this study. Santomier concluded that the bench press exhibited the greatest activity in the pectoralis major followed by the standing press. Santomier also concluded that antagonists and stabilizing muscles are trained as well as the prime movers.

Hinson (20) observed four different types of push-ups designed for women. The four exercises were the let-down push-up, bench push-up, knee-push-up and the full push-up. Two groups of ten women each were used in the investigation.

The lower ability group could do no more than five knee push-ups. The higher ability group could do at least ten full push-ups. The muscles under investigation were the triceps, deltoid, pectoralis major, trapezius, serratus anterior, rectus abdominus and external obliques. The rank order from low to high activity levels was the let-down push-up, knee push-up, bench push-up, and full push-up. Hinson noted a lack of efficiency and coordination of muscle function in the low ability group. Hinson also concluded that the let-down push-up was a valid exercise for pectoralis major development.

Randall (36) analyzed the pull-up and chin-up, but did not investigate the pectoralis major. Randall recommended observations of the pectoralis major, latissimus dorsi, teres major and posterior deltoid needed to be performed for a more complete comparison between the pull-up and chin-up. Santomier (38) recommended studies to be performed on different exercises for analysis of muscular involvement. The lack of information analyzing exercises for muscular development has been evident. Unfortunately, few analytical studies for development of muscles using appropriate exercises have appeared in the literature.

The use of the electromyographic technique has been well documented for the analysis of muscular activity. The procedures for conducting an electromyographic study have approached the degree of sophistication necessary for hypothesis testing. Electromyographic studies of pectoral musculature have been categorized as studies defining pectoralis major involvement in upper arm movements, analysis of sports skills utilizing the pectoralis major and analyses of the activity of pectoralis major during developmental exercises for the pectoralis major.

CHAPTER BIBLIOGRAPHY

1. Adrian, Marlene, "Cinematographic, Electromyographic and Electrogoniometric Techniques for Analyzing Human Movements," Exercise and Sport Sciences Reviews, edited by Jack H. Wilmore, New York, Academic Press, 1973.

2. Anderson, Jean P., "An Electromyographic Study of Ballistic Movement in the Tennis Forehand Drive," unpublished doctoral dissertation, Department of Physical Education, University of Minnesota, 1970.

3. Basmajian, John V., "Electromyographic Analyses of Basic Movement Patterns," Exercise and Sport Sciences Reviews, edited by Jack N. Wilmore, New York, Academic Press, 1973.

4. ________________, Muscles Alive: Their Function Revealed by Electromyography, Baltimore, Maryland, The Williams and Wilkins Co., 1967.

5. ________________ and F. J. Bazant, "Factors Preventing Downward Dislocation of the Adducted Shoulder Joint," Journal of Bone and Joint Surgery, XLI (October, 1957), 1182-1186.

6. ________________ and R. Elkus, "Endurance in Hanging by the Hands," American Journal of Physical Medicine, LII (June, 1973), 124-127.

7. Bearn, J. G., "An Electromyographic Study of the Trapesius, Deltoid, Pectoralis Major, Biceps and Triceps Muscles During Static Loading of the Upper Limb," The Anatomical Record, CXL (June, 1961), 103-197.

8. Bierman, William and Leonard J. Yamshon, "Electromyography in Kinesiologic Evaluations," Archives of Physical Medicine, XXIX (March, 1948), 206-211.

9. Bigland, Brenad and O. C. J. Lippold, "The Relation Between Force, Velocity and Integrated Electrical Activity in Human Muscles," Journal of Physiology, CXXIII (January, 1954), 214-224.

10. Clarke, David H. and H. Harrison Clarke, Research Processes in Physical Education, Recreation and Health, Englewood Cliffs, New Jersey, Prentice-Hall, Inc., 1970.

11. Crase, Leonard W., "A Study of Movements at the Humeroscapular, the Acromioclavicular and the Sternoclavicular Joints," unpublished master's thesis, Department of Physical Education for Men, University of Iowa, Iowa City, Iowa, 1950.

12. Daniels, Lucille, Marian Williams and Catherine Worthingham, Muscle Testing, 2nd ed., Philadelphia, W. B. Saunders Co., 1956.

13. Darcus, H. D. and Nancy Slater, "Amplitude of Pronation and Supination," Journal of Anatomy, LXXXVII (april, 1953), 169-184.

14. Dempster, Wilfrid T., "Mechanisms of Shoulder Movement," Archives of Phyiscal Medicine and Rehabilitation, XLVI (January, 1965), 49-70.

15. Finanger, Kenton E., "An Electromyographic Study of the Function of Selected Muscles Involved in the Throwing of the Discus," unpublished doctoral dissertation, Department of Physical Education for Men, University of Iowa, Iowa City, Iowa, 1969.

16. Garrison, Levon E., "Electromyographic-Cinematographic Study of Musclar Activity During the Golf Swing," unpublished doctoral dissertation, Department of Physical Education, Florida State University, Gainesville, Florida, 1963.

17. Hallet, Charles D., "An Electromyographic Comparison of Muscular Activity for the Sternocostal Pectoralis Major, Teres Major, and Latissimus Dorsi in Three Cross Hold Positions," unpublished master's thesis, Department of Physical Education, Western Illinois University, 1971.

18. Harding, Linda T., "An Electromyographic Study of Selected Arm Support Activities," unpublished master's thesis, Department of Physical Education for Women, University of Iowa, Iowa City, Iowa, 1967.

19. Hermann, George W., "An Electromyographic Study of Selected Muscles Involved in the Shot Put," Research Quarterly, XXXIII (March, 1962), 85-93.

20. Hinson, Marilyn M., "An Electromyographic Study of the Push-up for Women," Research Quarterly, XL (May, 1969), 305-311.

21. Inman, Verna T., J. G. Saunders, and LeRoy C. Abbot, "Observations on the Function of the Shoulder Joint," The Journal of Bone and Joint Surgery, XLII (January, 1944), 1-30.

22. Kamon, Eliezer, "Electromyographic Analysis of the Scissors Exercise Performed on the Pommel Horse," Journal of Sports Medicine, VI (December, 1966), 223-234.

23. _______________, "Electromyography of Static and Dynamic Postures of the Body Supported on the Arms," Journal of Applied Physiology, XXI (September, 1966), 1611-1618.

24. Kitzman, Eric W., "Baseball: Electromyographic Study of Batting Swing," Research Quarterly, XXXV (May, 1964), 166-178.

25. Lance, Brian M. and Don B. Chaffin, "The Effect of Prior Muscle Exertions on Simple Movements," Human Factors, XIII (August, 1971), 355-361.

26. Landa, Jean, "Shoulder Muscle Activity During Selected Skills on the Uneven Parallel Bars," Research Quarterly, XLV (May, 1964), 120-127.

27. Licht, Sidney, "History of Electrodiagnosis," Electrodiagnosis and Electromyography, 3rd ed., edited by Sidney Licht, Baltimore, Waverly Press, Inc., 1971.

28. Lippold, O. C. J., J. W. T. Redfearn, and J. Vuco, "The Electromyography of Fatigue," Ergonomics, III (January, 1960), 121-131.

29. _______________, "The Relationship Between the Stretch Reflex and the Electrical and Mechanical Rhythmicity in Human Voluntary Muscle," Journal of Physiology, CXXXVIII (July, 1957), 14P-15P.

30. Lloyd, Andree J., "Surface Electromyography During Sustained Isometric Contractions," Journal of Applied Physiology, XXX (May, 1971), 713-719.

31. Mapes, Donald F., "Electromyographic Study of Functions of Selected Mscles in: Check Action, Ballistic Movement and Follow-Through During the Baseball Throw," unpublished doctoral dissertation, Department of Physical Education for Men, University of Iowa, Iowa City, Iowa, 1974.

32. McCloy, C. H., "Some Notes on Differential Actions of Partite Muscles," Research Quarterly, XVII (December, 1946), 254-263.

33. Miles, Meryl, C. A. Martensen and W. E. Sulivan, "Electromyography During Normal Voluntary Movement," Anatomical Record, XCVIII (May-August, 1947), 209-218.

34. O'Connell, A. L. and E. B. Gardner, "The Use of Electromyography in Kinesiological Research," Research Quarterly, XXVIV (May, 1963), 166-184.

35. Partridge, Lloyd and Frances Huber, "Factors in the Interpretation of the Electromyogram Based on Muscle Response to Dynamic Nerve Signals," American Journal of Physical Medicine, XLVI (December, 1967), 1276-1289.

36. Randall, Nellie G., "An Electromyographic Study of Selected Muscles Involved in Two Methods of Chinning," unpublished doctoral dissertation, Department of Physical Education for Women, University of Iowa, Iowa City, Iowa, 1963.

37. Rice, Mary Agnes, "An Electromyographic Study of Specific Muscles Involved in the LaCrosse Cradle," unpublished doctoral dissertation, Department of Physical Education, Temple University, Philadelphia, Pennsylvania, 1969.

38. Snatomier, James P., "An Electromyographic Analysis of Specific Muscles Used in Performing Selected Isotonic Weight Training Activities," unpublished doctoral dissertation, College of Health, Physical Education and Recreation, University of Utah, Salt Lake City, Utah, 1971.

39. Scheving, Lawrence E. and John E. Pauly, "An Electromyographic Study of Some Muscles Acting on the Upper Extremity of Man," The Anatomical Record, CXXXV (December, 1959), 239-245.

40. Shambes, Georgia M. and Joan C. Waterland, "Control of Motor Units in Skill and Postural Muscles in Normal Man," American Journal of Physical Medicine, LII (June, 1973), 114-123.

41. Shevlin, Geraldine M. Justus F. Lehmann, and Jennie A. Lucci, "Electromyographic Study of the Function of Some Muscles Crossing the Glenohumeral Joint," Archives of Physical Medicine, L (May, 1969), 264-270.

42. Sigerseth, P. O. and C. N. McCloy, "Electromyographic Study of Selected Muscles Involved in Movements of Upper Arm of Scapulohumeral Joint," Research Quarterly, XXVII (December, 1956), 409-417.

43. Slater-Hammel, Arthur T., "Action Current Study of Contraction-Movement Relationships in Golf Stroke," Research Quarterly, XIX (December, 1948), 164-176.

44. ________________________, "An Action Current Study of Contraction-Movement Relationships in the Tennis Stroke," Research Quarterly, XX (December, 1949), 424-431.

45. Slaughter, Duane R., "Electromyographic Studies of Arm Movements," Research Quarterly, XXX (October, 1959), 326-337.

46. Stetson, R. N. and H. D. Bouman, "The Action-Current as Measure of Muscle Contraction," Science, LXXVII (February, 1933), 219-221.

47. Wells, Katherine F., Kinesiology, 5th ed., Philadelphia, W. B. Saunders Co., 1971.

48. Wilcott, R. C. and H. G. Beenken, "Relation of Integrated Surface Electromyography and Muscle Tension," Perceptual and Motor Skills, VII (December, 1957), 295-298.

CHAPTER III

PROCEDURES OF THE STUDY

Selection of the Sample

The subjects utilized for this experiment were comprised of 34 volunteer students incidentally sampled from required undergraduate physical education classes during the spring semester of 1976. Students volunteered for the proposed investigation and upon initial contact with the students, several items were discussed. First, a brief discussion as to the nature of the study was mentioned, and the title and statement of the problem were presented, and any questions at that time were entertained. Secondly, some of the unique procedures of electromyography were reviewed. The students were told that skin would have to be abraded and electrodes placed in a bipolar configuration over the motor points. A brief visual approximation of the location of the two motor points involved was illustrated. The final consideration of the initial meeting was the fact that two meetings were needed. The first meeting was to take place at the North Texas State University's Human Performance Laboratory. The second meeting would take place at Texas Woman's University where the necessary equipment and facilities were available for the final meeting. At this point, it was announced that transportation would be provided for the final meeting at Texas Woman's University. The volunteer subjects then signed a time schedule for the final meeting.

While thirty-four male students originally expressed an interest and volunteered for the study, four subjects failed to meet both scheduled testing sessions, therefore, a total of thirty subjects completed the testing. Twenty-one of the thirty subjects came from two upper division physical education classes for physical education majors. It was assumed that this population would be able to adequately perform the exercises and that their interest in physical education would serve as a motivation to participate and complete the requirements for the investigation. The two upper division classes were PHED 305 Section 002 Kinesiology and PHED 433 Section 001 Measurement in Health and Physical Education. The remainder of the volunteer subjects came from PHED 154 Section 501 Handball-Racketball, an activity class for non-majors.

The mean height of the subjects was 69.69 inches. The range of height was from 63.5 to 74.5 inches with a standard deviation of 2.58 inches. The mean subject weight was 170.24 pounds. The subjects ranged from 124.5 to 246.25 pounds with a standard deviation of 26.42 pounds. The mean age of the sample population was 22.44 years.

A range of 18.33 to 28.75 years and a standard deviation of 2.63 years defined the sample.

Screening of Subjects

Screening the subjects was necessary to establish the fact that each volunteer subject could perform each of the exercises and that each subject could maintain the established cadence. The first meeting at North Texas State University's Human Performance Laboratory was primarily to obtain descriptive data of the sample and to ascertain if the subjects could perform the exercises at the desired rate of speed. A secondary purpose was to complete the Use of Human Subject form (Appendix A) as suggested by the North Texas State University committee on the use of human subjects in research. A similar format (Appendix B) had to be completed for the opportunity to collect data at Texas Woman's University. Upon entering the laboratory the subjects were asked to read and then sign the necessary form.

Subjects were then asked to remove their shoes. At this time height and weight were recorded on the data sheet (Appendix C). The age of each subject was recorded in terms of years and to the nearest month. For computational purposes age was later converted to years and the nearest one-hundredth of a year.

A brief description of the cadence to be used followed the collection of descriptive data. It was emphasized to the subjects that this cadence was needed for the control of speed of each treatment so that each treatment was to have the same duration as compared to ensuing treatments. The cadence with the aid of a stop watch used was up-two-three, down-two-three. For orientation purposes the subjects were told that at the sound of the first "three" they should be at the maximum height of the exercise. At the sound of the second "three" they were to be back at the resting position. Maintaining a smooth motion throughout the exercise was emphasized. A demonstration of the cadence while a dip was performed concluded the directions for performance.

The volunteer subjects completed one trial of each of the six exercises. If some doubt was encountered as to the ability of the subject to maintain the cadence, a retrial of the same exercise was performed. If a subject was unable to perform the exercise properly, he was dismissed from the study.

The first exercise to be performed was the dip. The dip was initiated from a position in which the upper arm was parallel to the floor. The maximal height of the dip was defined as when the elbow was completely extended. The subject then lowered himself back to the starting position (see Figure 1, page 55).

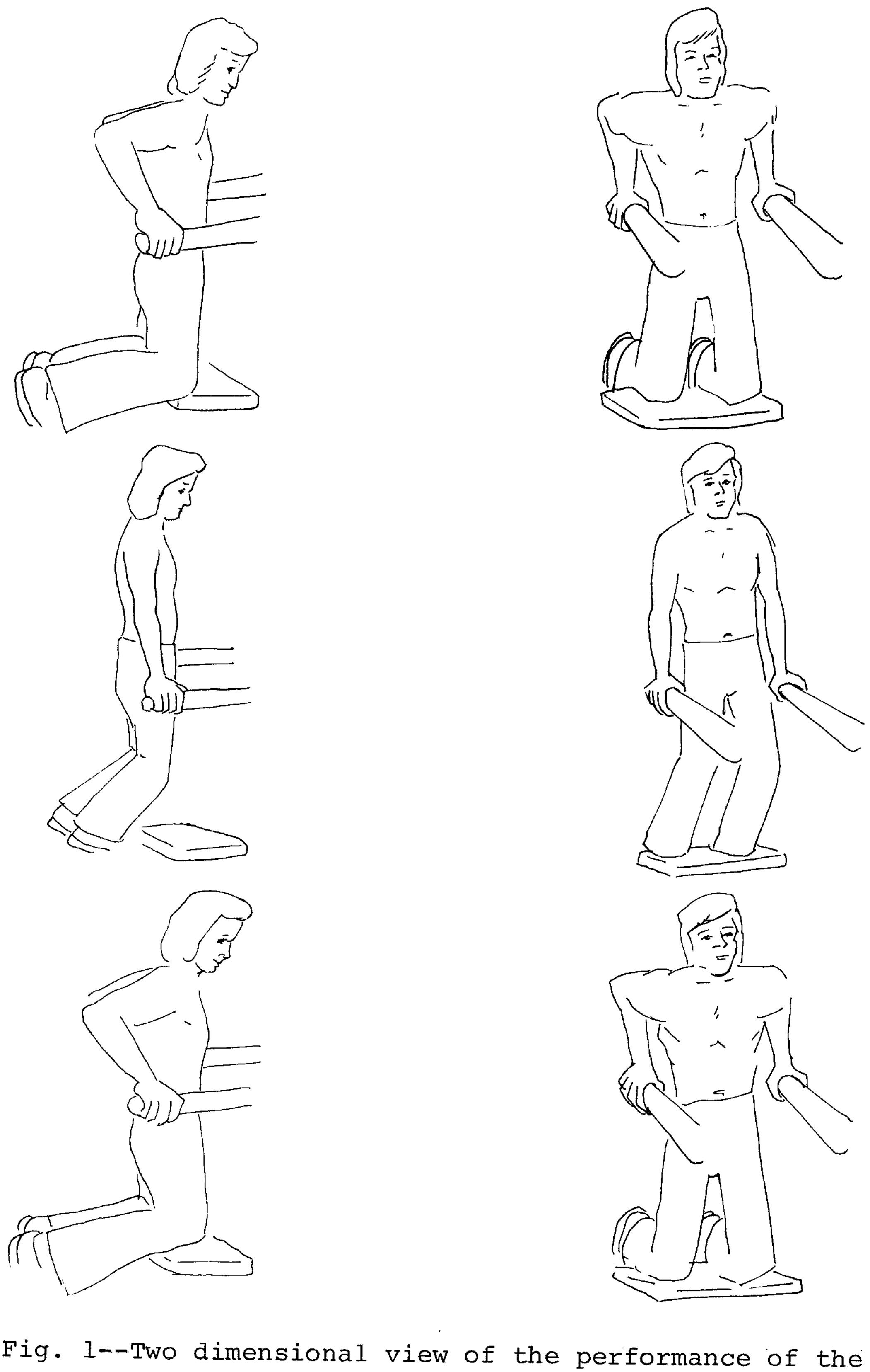

Fig. 1--Two dimensional view of the performance of the dip

The second exercise to be executed was the sit-down push-up. The subject rested his heels on a box elevating his feet twelve inches. His hands were also placed upon a box directly behind him in such a manner as to elevate his hands twelve inches. The subject was seated on the floor and from this starting position, the subject lifted himself from the starting position (see Figure 2, page 57).

The third exercise was the push-up. The subject started the push-up from a prone position with his hands placed under the humeroscapular joint. From this position, the subject pushed to a position where the arms were fully extended. The push-up was completed when the subject lowered to the starting position (see Figure 3, page 58).

A wide push-up followed the regular push-up. The same performance was expected of the subject as the regular push-up, but with the hands placed further apart. The hands were positioned in such a way that the distance between the subject's hands equaled one and one-half the distance between a subject's humeroscapular articulations (see Figure 4, page 59).

Following the wide push-up, the subjects were asked to perform a pull-up. The starting position was defined as the hands pronated, arms extended and hands placed shoulder width apart. From the starting position the subject pulled in such a manner to a position where his chin

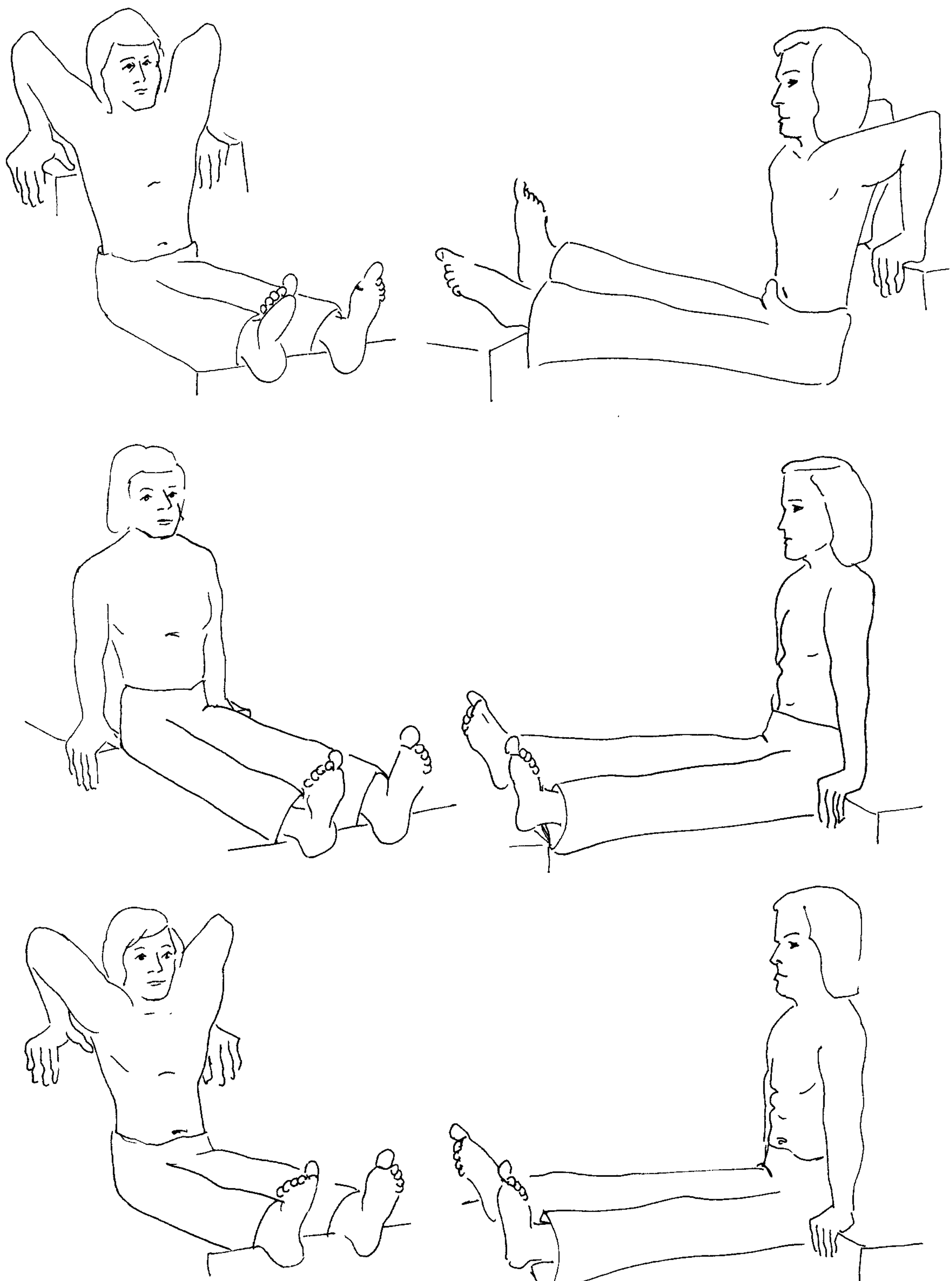

Fig. 2--Two dimensional view of the performance of the sit-down push-up

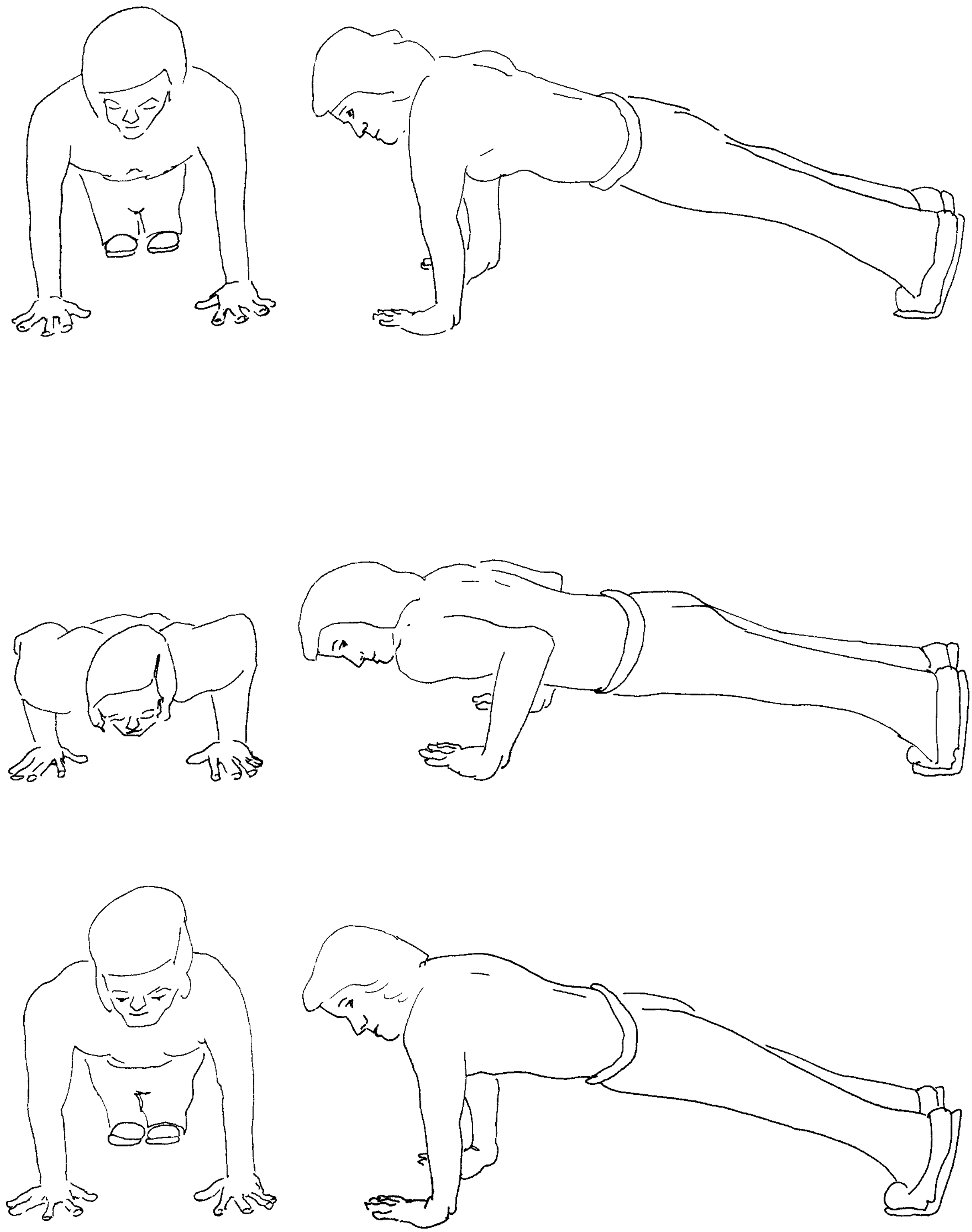

Fig. 3--Two dimensional view of the performance of the push-up

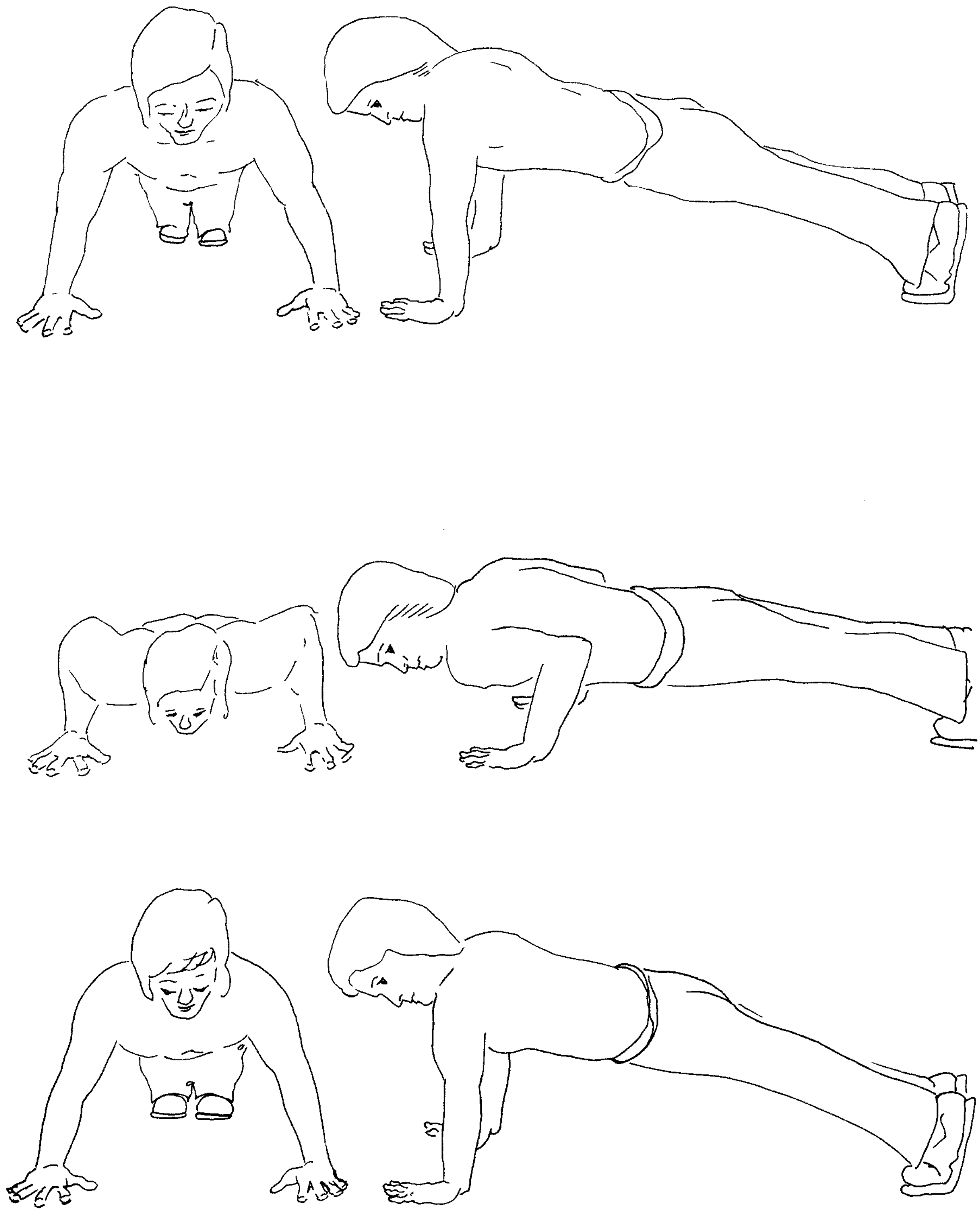

Fig. 4--Two dimensional view of the performance of the wide push-up

was even with the bar. The pull-up was completed when the subject assumed the starting position (see Figure 5, page 61).

The final exercise was the chin-up. The starting position was similar to the pull-up except that the hands were supinated. From the starting position, the subject pulled until his chin was level with the bar and then lowered himself to the starting position (see Figure 6, page 62).

The final responsibility of the first meeting was for the subjects to select a time for the final meeting. With the subject's signature on the testing schedule, he had completed the criterion of the first meeting. The subjects were then advised of the transportation availability, meeting place and informed that clothing would not be a factor in the final testing.

Design of the Study

The study was designed as a split plot factorial experiment utilizing a 2 X 6 factorial design with repeated measures. One main effect of the study was portions of the pectoralis major, the clavicular and sternal segments. The second main effect of the study was the six exercises under investigation. Simultaneous measures of the two sections of the pectoralis major were recorded for each exercise and served as the repeated measures dimension in the experimental design. The independent variables were the two

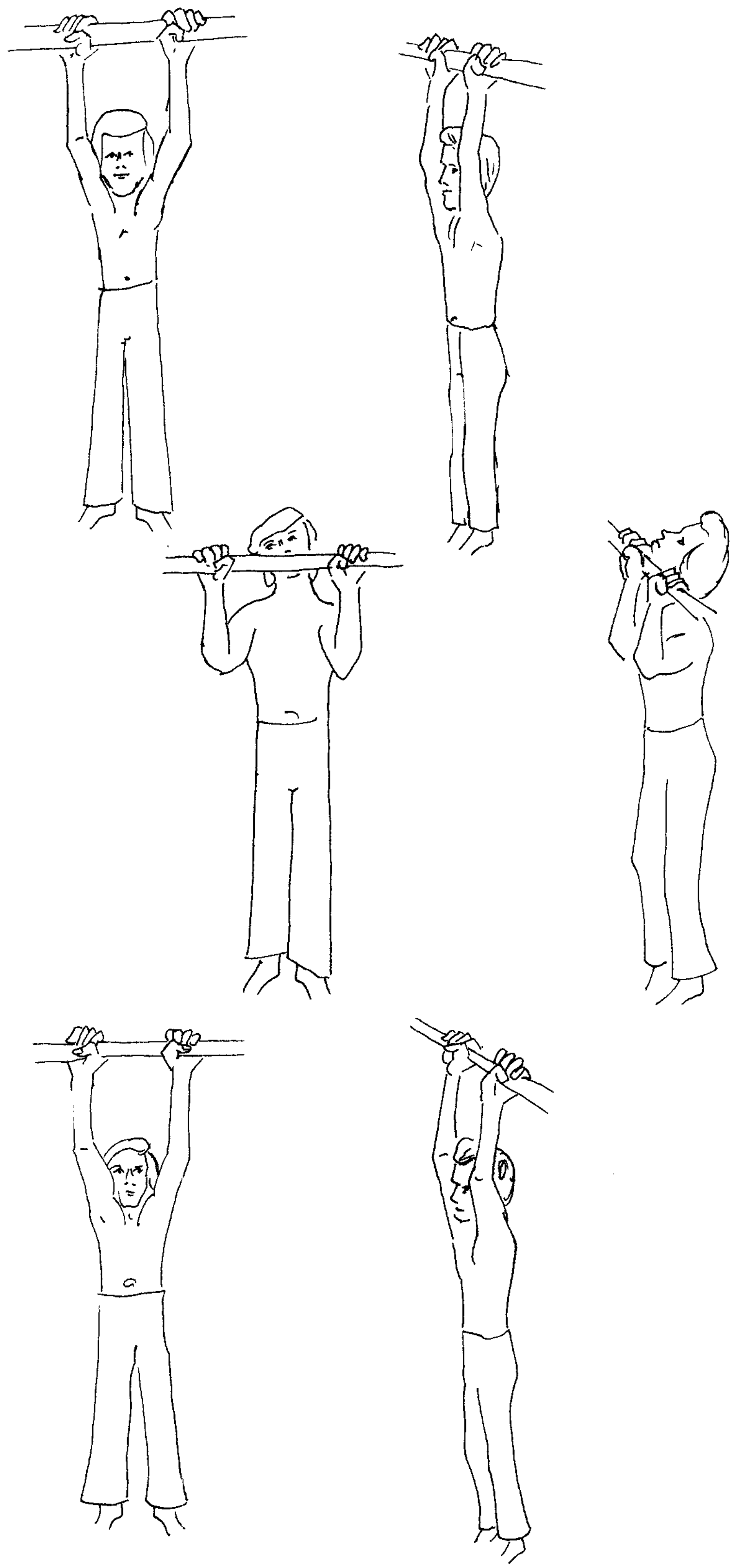

Fig. 5--Two dimensional view of the performance of the pull-up

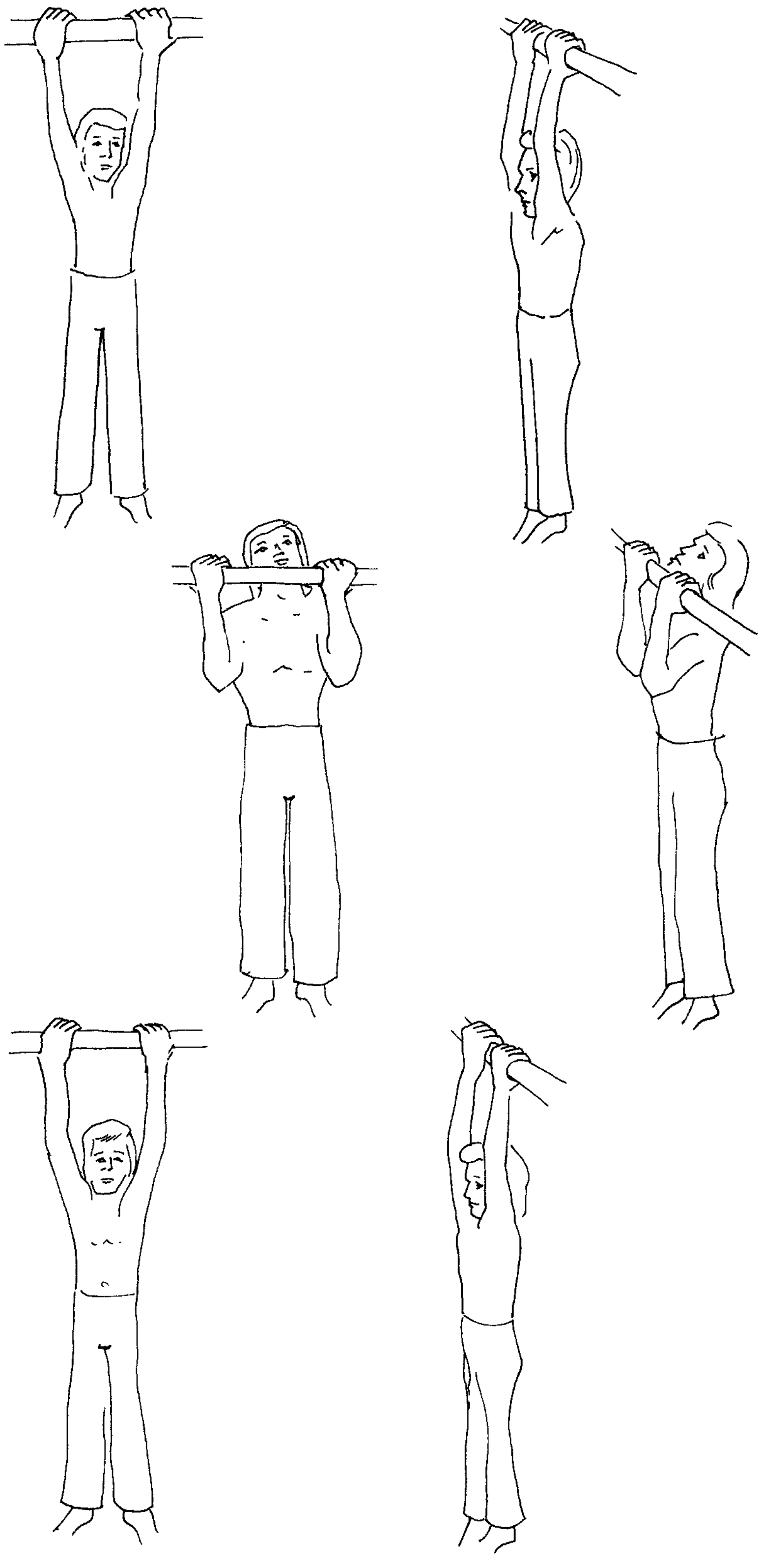

Fig. 6--Two dimensional view of the performance of the chin-up

portions of the pectoralis major and the six selected exercises, and the dependent variable was the integrated digital output that represented muscular activity.

Treatments were randomly selected for each subject by drawing numbers out of a hat. Each number from 1 through 6 represented one of the exercises under investigation. The order of the selected numbers representing each exercise was the order in which a subject executed the treatments during the final investigation. An order of treatments for each subject was selected, described in the above procedure. The randomization of the order of exercises for each subject was to counteract any effect that could tontaminate the data and produce inflated scores due to the onset of fatigue.

Control of Fatigue

The control for fatigue artifacts was essential for electromyographic comparisons to be valid. In fatigued muscles electromyographic activity may have appeared inflated compared to the baseline measures in nonfatigued muscles while executing the same motor skill. Two procedures were used to control for the effects of fatigue and were designed to maintain baseline measures in the pectoralis major throughout the testing session. The first procedure was to limit the number of trials for each exercise to one repetition. Previous investigations have used multiple trials and the computed mean score for the trial was used for analysis purposes. The possibility of fatigue artifacts occurring with the six selected exercises using multiple trials was too great for valid measurements of pectoralis major activity to be obtained, thus the use of one observation per subject performing each exercise was felt warranted.

The second procedure for control of fatigue artifacts was to introduce a rest period between exercises. Gutin (4) suggested two minutes of rest between exercises in his classical study of the rectus abdominus. Hinson (7) used three minute rest periods between exercises to control for the influence of fatigue while observing the pectoralis major during four types of push-ups. Results of a pilot study suggested that three minute rest periods were insufficient to control for the influence of fatigue while using electromyographic techniques. Therefore, five minute rest periods between treatments was used to combat the influence of fatigue and maintain baseline measures. With the use of only one trial and five minute rest periods it was assumed that fatigue was controlled and valid comparisons of pectoralis major activity during the six exercises was obtained.

Instrumentation of the Study

The signal from both sections of the pectoralis major was integrated by two Newport Laboratories model 100 integrators. Adrian (1, p.353) suggested that integrated electromyograms were the most precise form of analysis of electromyography. The integrated signal, representing the intensity of pectoralis major contraction, was displayed on two digital displays. Two Hewlett-Packard displays Model 5300A and Model H22 5211B were used and the digitalized output display was used as the dependent variable for statistical analysis.

Six surface electrodes comprised the circuitry needed for monitoring the pectoralis major. Narco Bio-Systems 11 millimeter surface electrodes part number 710-0010 were used throughout the investigation. Electrodes were adhered to the skin with Narco Bio-System part number 710-0013 adhesive washers. To insure conductivity between skin and electrode, Narco Bio-System part number 710-0014 electrode paste was used.

Skin Preparation and Electrode Placement

Skin preparation for the attachment of electrodes was based upon a review of existing procedures. The area where electrodes were placed was shaved if body hair of the subject indicated this procedure. Mapes (8) and Randall (9) indicated the need of hair removal for secure adhesion of the electrodes to the body surface. The skin of the subjects was abraded with sandpaper as described by Mapes (8) and Harding (6). The area of concern was then washed with alcohol as described by Santomier (10). Hinson (7) suggests skin penetration with needles to insure low resistance and conductivity. This procedure was performed with pins driven through the center of the cork with the points extended beyond the cork. The cork with the exposed pin points was applied to the skin where the electrodes were placed. This final procedure completed skin preparation.

Surface electrodes were used in this study. Adrian (1) suggests that surface electrodes express a more global interpretation of total muscular activity. Adrian (1) concludes that needle electrodes tend to express limited regional activity. Total muscle involvement was under investigation and thus required the use of surface electrodes.

A bipolar lead system was used throughout the study. Clarke and Clarke (3) maintained that bipolar leads are more efficient for kinesiological research than monopolar leads. Interelectrode distance was standardized at one centimeter as Hallet (5) suggested. Santomier (10) had suggested two and one-half centimeters and Anderson (2) suggested two centimeters for interelectrode distance. Santomier and Anderson allowed for greater skin resistance which may have been reflected in the greater distance between electrodes. Electrodes were secured to the skin with adhesive washers designed for that purpose. Skin resistance was reduced to 5,000 ohms as suggested by Harding (6) and Mapes (8). Randall (9) reported a controlled skin resistance of 5,000 to 10,000 ohms. Santomier (10) reported skin resistance below 15,000 ohms. The use of 5,000 ohms for skin resistance appeared to be more widely accepted and thus was used for the target skin resistance in this investigation.

Electrode placement was determined according to Hinson's (7) study. A bipolar lead with one centimeter interelectrode distance was placed over the motor points of the sternal and clavicular portion of the pectoralis major. Hinson (7, p.307) located the position of the motor points and used the electrode placement described above. The clavicular motor point was defined as inferior to the midpoint of the clavicle and the sternal motor point was positioned over the midpoint of the anterior border of the axillary space. With the four electrodes in place, skin resistance was measured and was never over 5,000 ohms. Two ground electrodes were placed over the anterior surface of the wrist to complete the electromyographic circuitry.

Collection of the Data

The final meeting with the subjects was for the purpose of gathering the data needed for analysis of the six exercises. The subjects were transported to the Human Performance Laboratory at Texas Woman's University. Upon arrival at the laboratory, the subjects were asked to remove their shirts. While the subjects were complying with this request, the Newport Laboratories integrators and the Hewlett-Packard digital displays were turned on to warm-up. The equipment needed for the exercises was gathered and positioned according to the limitations of space provided from the confines of the room and the length of the cables leading to the electrodes.

Each subject had the basic skin preparation of hair shaved, skin abraded with sandpaper, washed with alcohol, and skin penetration with the pin filled cork at the electrode sites. The electrodes were then placed over the motor points using bipolar lead circuitry (see Figure 7, page 69).

After electrode placement on each subject was completed the equipment was calibrated. Thirty minutes of warm-up was needed for proper functioning of the integrators according to the procedures for operation derived from the manual that accompanied the equipment. The equipment was given the allotted time for reliable performance.

Each subject's skin resistance was measured with an ohmmeter before the first treatment. The skin resistance was never above 5,000 ohms during the final testing. The subjects during any given test session alternated so that during the first subject's rest period the other subjects were tested. Generally, four subjects were tested during a test session and five minutes of rest was provided each subject between each exercise bout. Therefore, in five minutes, all subjects completed the first treatment. After

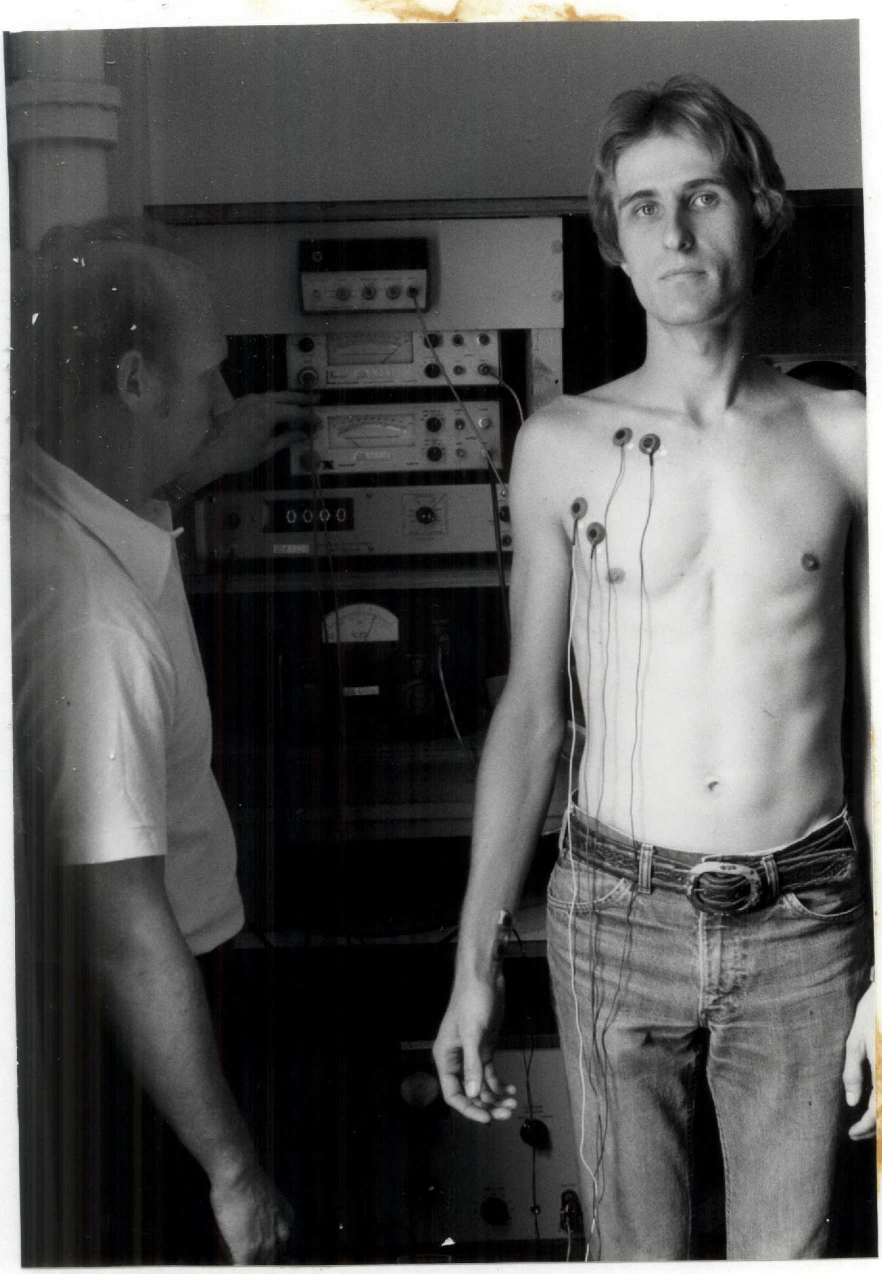

Fig. 7--Electromyographic equipment used in the study and placement of electrodes on a subject

the first series of tests, the order of subjects was established and continuous testing with the ordered subjects was possible, following each individual's random sequence of exercises. The exercises were performed to the same cadence as the first meeting at the Human Performance Laboratory of North Texas State University. If a malfunction in the equipment, or the separation of an electrode occurred, or if the subject was unable to maintain the cadence, a retrial of the same exercise was given after five minutes of rest. Only one trial for each exercise was performed. The data was recorded on each subject's data sheet (Appendix C).

At the end of each testing session the integrators were calibrated. To complete a testing session, the electrodes were cleaned and placed in the proper place, the equipment turned off, and the room arranged to its original condition. The volunteer subjects were transported to North Texas State University and appreciative recognition given for their cooperation.

Analysis of the Data

Upon completion of the data collection, electromyographical activity was collected on the six selected exercises with simultaneous recordings of the two portions of the pectoralis major muscle. The two main effects of the experiment, the selected exercises and the portions of the pectoralis major were clearly defined and data obtained for each main effect. The electromyographical data served as the dependent variable in analyzing the main effects.

A two-way analysis of variance with repeated measures was performed on the data. When the interaction F-ratio was found to be significant, Duncan's multiple comparison test designed to show where differences existed was used on the combined mean score of the two sections of the pectoralis major. With Duncan's test, comparisons of the exercises in terms of total pectoralis major involvement could be analyzed.

The electromyographical activity for each exercise was analyzed for the sternal segment and the clavicular segment of the pectoralis major. A one-way analysis of variance with repeated measures was performed on each portion of the pectoralis major. Duncan's multiple comparison tests were also used to examine where differences existed. This procedure allowed for the comparison of the individual sections of the pectoralis major to the selected exercises.

The program STO 17 was used in conjunction with the IBM 360 computer for analysis of the data. The level of significance was set at the .05 level for acceptance or rejection purposes. The .05 level was used throughout the investigation in conjunction with the statistical treatments.

CHAPTER BIBLIOGRAPHY

1. Adrian, Marlene, "Cinematographic, Electromyographic, and Electrogoniometric Techniques for Analyzing Human Movements," Exercise and Sport Sciences Reviews, edited by Mack N. Wilmore, New York, Academic Press, 1973.

2. Anderson, Jean P., "An Electromyographic Study of Ballistic Movement in the Tennis Forehand Drive," unpublished doctoral dissertation, Department of Physical Education, University of Minnesota, 1970.

3. Clarke, David H. and H. Harrison Clarke, Research Processes in Physical Education, Recreation and Health, Englewood Cliffs, Prentice-Hall, Inc., 1970.

4. Gutin, Bernard and Stanley Lipetz, "An Electromyographic Investigation of the Rectus Abdominus in Abdominal Exercises," Research Quarterly, XLII (October, 1971), 256-263.

5. Hallet, Charles D., "An Electromyographic Comparison of Muscular Activity for the Sternocostal Pectoralis Major, Teres Major, and Latissimus Dorsi in Three Cross Hold Positions," unpublished master's thesis, Department of Physical Education, Western Illinois University, August, 1971.

6. Harding, Linda Taylor, "An Electromyographis Study of Selected Arm Support Activities," unpublished master's thesis, Department of Physical Education, University of Iowa, Iowa City, Iowa, June, 1967.

7. Hinson, Marilyn M., "An Electromyographic Study of the Push-up for Women," Research Quarterly, XL (May, 1969), 305-311.

8. Mapes, Donald F., "Electromyographic Study of the Functions of Selected Muscles in: Check Action, Ballistic Movement and Follow-Through During the Baseball Throw," unpublished doctoral dissertation, Department of Physical Education, University of Iowa, Iowa City, Iowa, 1964.

9. Randall, Nellie G., "An Electromyographic Study of Selected Muscles Involved in Two Methods of Chinning," unpublished doctoral dissertation, Department of Physical Education for Women, University of Iowa, Iowa City, Iowa, 1963.

10. Santomier, James P., "An Electromyographic Analysis of Specific Muscles Used in Performing Selected Isotonic Weight Training Activities," unpublished doctoral dissertation, College of Health, Physical Education and Recreation, University of Utah, Salt Lake City, Utah, 1971.

CHAPTER IV

RESULTS OF THE STUDY

Results of Two-Way Analysis of Variance of the Segments Versus Exercises

The data used for analysis was derived from the ditigalized integrated activity which represented muscular activity. Based upon the results of the two-way analysis of variance, the sternal segment activity was significantly greater than the clavicular portion. A significant difference existed among the exercises in terms of the mean electromyographic activity of the sternal and clavicular segments of the pectoralis major. Interaction between the two main effects, segments of the pectoralis major and exercises, was also determined to be significant. Duncan's multiple comparison test was used on the combined means, the means associated with the clavicular segment and the means associated with the sternal segment to determine where differences existed and to establish an order effect of muscular activity.

The main effect of exercises when analyzed revealed an F-ratio of 12.539. The F-ratio associated with the degrees of freedom yielded a probability beyond .0001. To achieve significance the .05 level was chosen and therefore, the main effect of exercise was well beyond the acceptable values for significance. (See Table I.)

TABLE I

SUMMARY TABLE OF TWO-WAY ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sums of Squares	Variance Estimate	F-Ratio	Probability
Between Subject	179	15351441	. . .	. . .	. . .
Groups	5	4066210	813242	12.539	.0001
Error Between	174	11285230	64857	. . .	. . .
Within Subjects	180	12731523	. . .	. . .	. . .
Treatments	1	3582222	3582222	76.813	.0001
Interaction	5	1034686	206937	4.437	.00079
Error Within	174	8114615	46635	. . .	. . .
Total	359	28082964	. . .	. . .	. . .

A statistical difference was evidenced among the exercises. Three possible explanations were considered. First, the exercises selected were executed with several muscles that were not under investigation, and the execution of the selected exercises involving other muscles and muscle groups could have influenced pectoralis major involvement which would have been reflected in electromyographic activity. Secondly, the range of motion of the humerus was not consisent between exercises. The humerus during the pull-up and chin-up rotated nearly 180 degrees. While executing the dip and push-up, the range of the humerus was approximately 90 degrees. The range of motion of the humerus would influence pectoralis major involvement. A third possibility for the observed differences could have been reflected in the amount of weight the humerus had to lift to execute the exercise. During the pull-up, dip, and chin-up, all subject's weight was supported with his hands. During the two push-ups and the sit-down push-up a portion of the weight or resistance was supported by the feet. Thus, resistance was not constant though each subject's weight acted as its own control. The variance attributable to exercise may have been reflected in one or any combinations of the three explanations listed above.

A computed F-ratio of 76.813 was determined for the main effect of portions of the pectoralis major. The F-ratio with the associated degrees of freedom, yielded a probability beyond the .0001 level of significance. The .0001 level of significance was well beyond the .05 level chosen as the acceptable probability for significant difference. (See Table I.)

The electromyographical activity difference between the sternal and clavicular portion of the pectoralis major was significant. The greater activity in the sternal portion may be attributable to three explanations. First of all, the sternal portion is larger than the clavicular segment. More motor units may be operational in the sternal portion and thus create more electrical activity. Secondly, the possibility exists that the selection of exercises favor the activity of the sternal fibers. The third explanation was that the anterior deltoid, because of its position, may have functionally the same line of force as the clavicular portion of the pectoralis major and materially contributed to the pulling action during arm movements. Since functional similarities exists between the clavicular segment and the anterior deltoid, the clavicular segment's activity may be influenced by the anterior deltoid. This influence could cause deltoid activity in the clavicular segment movements. The variance between the clavicular and sternal segments may be attributable to one, or any combination, of the three considerations listed above.

The interaction F-ratio of segments by exercises was computed to be 4.437. The computed F-ratio with the associated degrees of freedom yielded a probability of .00079. The interaction level of significance was well beyond the .05 level of significance needed for determining a statistical difference. (See Table I.)

A graphic representation of sternal and clavicular segments electromyographic activity for the six selected exercises demonstrated the interaction significance. (See Figure 8, page 79.) The slopes of the lines are not parallel which indicates that interaction was operational during the selected exercises. Thus an increase in sternal activity was not accompanied by the same increase in clavicular activity throughout the exercises. The interaction of exercises and segments suggested that choice of exercises influenced segmented activity of the pectoralis major.

The dip, as illustrated in Figure 8, produced the most activity in the sternal pectoralis major. The least activity recorded in the sternal portion was observed during the execution of the sit-down push-up. The rank order of exercises for production of sternal pectoralis major involvement from lowest electromyographic activity was sit-down push-up, chin-up, wide push-up, pull-up, push-up, and dip. The dip, as illustrated in Figure 8, also produced the greatest involvement of the clavicular portion of the pectoralis major than any of the other exercises. The least activity was observed in the chin-up. The rank order of exercises from low to high activity levels for the clavicular segment of the pectoralis

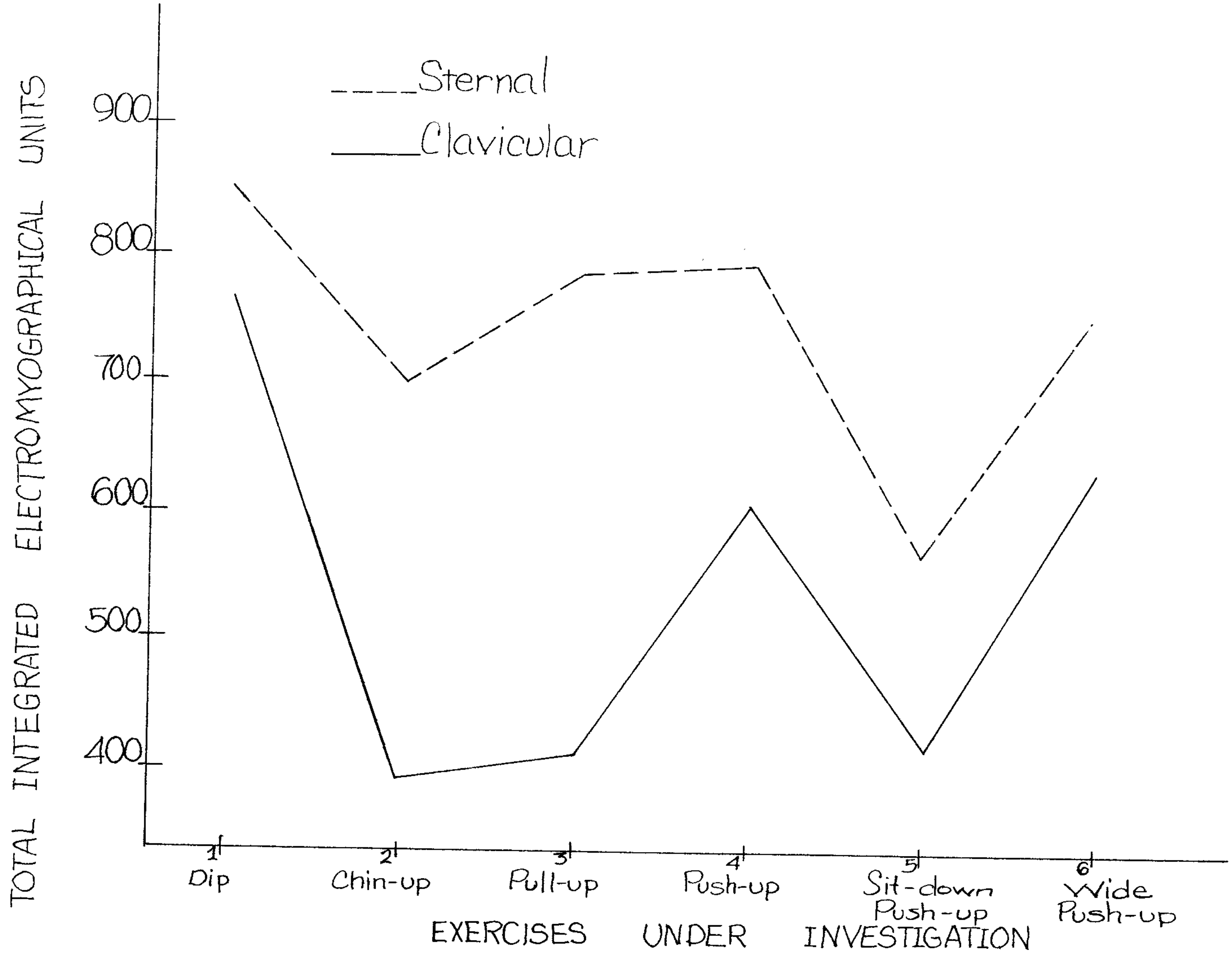

Fig. 8--Means of sternal and clavicular pectoralis major activity during six selected exercises.

major was chin-up, pull-up, sit-down push-up, push-up, wide push-up and dip.

Since interaction was significant, Duncan's multiple comparison test was used on the combined means of the segments for comparison of the exercises. The use of Duncan's test established where significant differences existed when comparing each exercise with the five remaining exercises. When matching each exercise with the remaining exercises, fifteen comparisons were possible. The .05 level of significance was chosen to establish where significant differences between the fifteen possible comparisons occurred.

Duncan's Multiple Comparison of Combined Means

The use of combined means of the sternal and clavicular portion of the pectoralis major were used for analysis purposes. The combination of the means expressed a total muscular involvement. The rank order of combined means from lowest to highest activity level was the sit-down push-up, chin-up, pull-up, push-up, wide push-up and the dip. (See Figure 9, page 81.)

Of the fifteen comparisons that were possible, twelve of the comparisons were significant. (See Figure 10, page 82.) The activity of the dip was significantly greater than any other exercise. The activity of the dip could have been greater than the pull-up or chin-up because of involvement of the latissimus dorsi during the pull-up and chin-up.

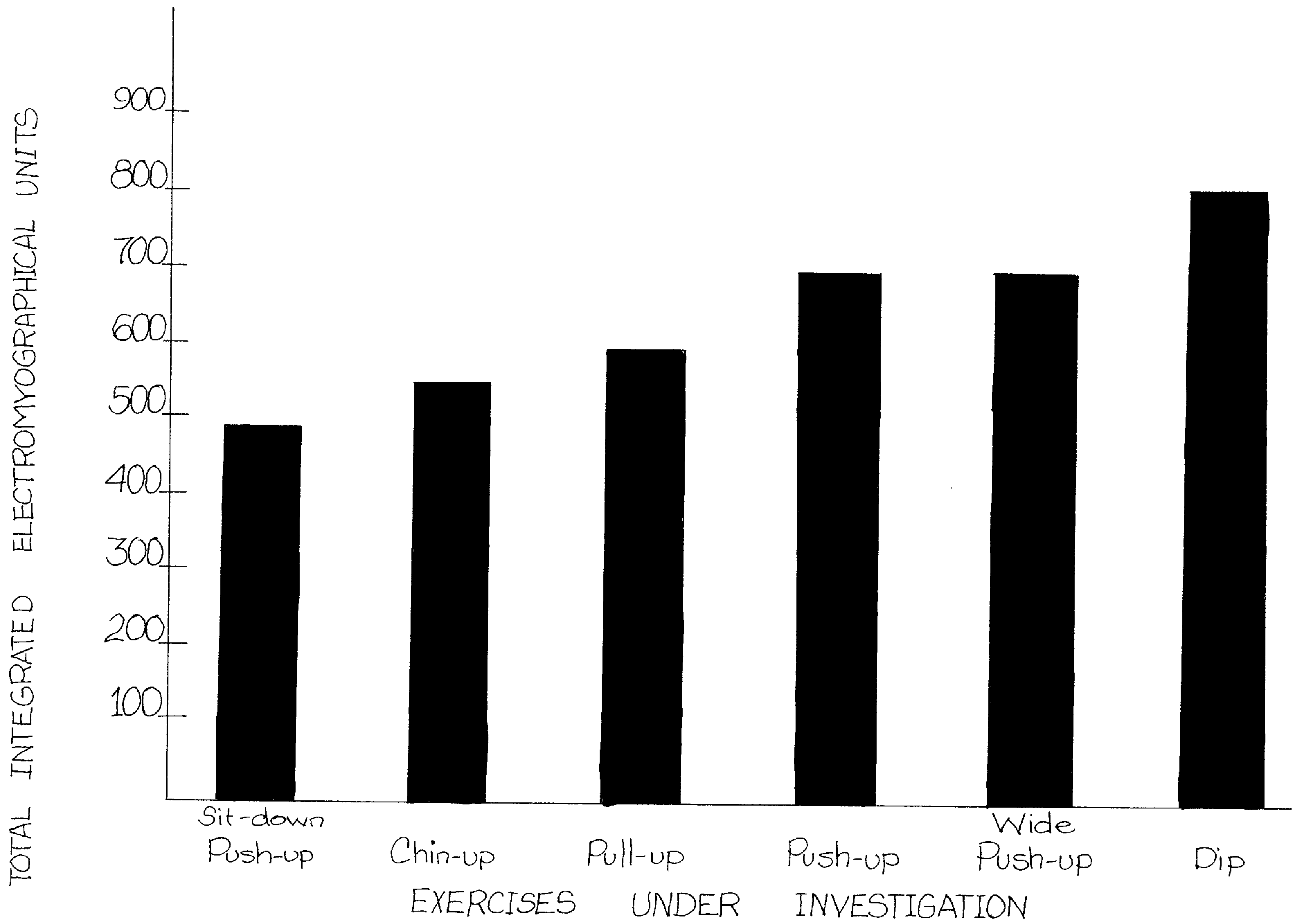

Fig. 9--Rank order of combined means in electromyographical units for the six selected exercises.

	Sit-Down Push-Up	Chin-Up	Pull-Up	Push-Up	Wide Push-Up	Dip
Sit-Down Push-Up	. .	91.13	95.38*	99.19**	101.56**	103.43**
Chin-Up	. .	. .	91.13	95.93**	99.12**	101.56**
Pull-Up	. .	. .	. .	91.13*	95.94*	99.19**
Push-Up	. .	. .	. .	. .	91.13	95.94*
Wide Push-Up	. .	. .	. .	. .	. .	91.14*
Dip	. .	. .	. .	. .	. .	. .

* = .05 level. ** = .01 level.

Fig. 10--Matrix of Duncan's multiple comparisons of combined means.

The activity of the dip could have been greater than the activity in the push-up, sit-down push-up and the wide push-up due to the reduced resistance gained by the support of the feet. The wide push-up activity was greater than the activity of the pull-up and chin-up possibly because of the involvement of the latissimus dorsi. The wide push-up activity was greater than the activity of the sit-down push-up possibly due to the longer distance between the point of application of force and the fulcrum. The longer lever would require greater force to move a similar amount of weight since the body would act as a third class lever. The push-up activity was significantly greater than the activity of the sit-down push-up, pull-up and chin-up. The greater activity of the push-up could have possibly required more activity in the pectoralis major than the sit-down push-up because of the distance from fulcrum to the application of force. The third class lever has a unique property of requiring more force to lift the same weight as the resistance arm increases. The push-up activity was significantly greater than the activity of the pull-up and chin-up. The latissimus dorsi has been recorded as one of the prime movers during the pull-up and chin-up, but had limited involvement in the push-up. Therefore, the push-up would not have the advantage of the latissimus dorsi and the pectoralis major would exhibit greater activity. The pull-up exhibited significantly greater activity in the pectoralis major than the activity in the sit-down push-up. The variance between the activity of the sit-down push-up and the activity in the pull-up may be attributable to two considerations. First, during the pull-up, the humerus travels through a 180 degree arc. The sit-down push-up requires approximately a 90 degree arc. The pectoralis major could have been more active in the pull-up because of the greater distance the humerus traveled. The second consideration that may have influenced the activity of the pull-up was the entire weight of a subject had to be pulled in opposition to gravity. During the sit-down push-up the arm action is opposing only a fraction of a subject's weight because of the support function of the feet. Therefore, either of the above conditions could have influenced pectoralis major activity and displayed more activity during the pull-up. All other comparisons were insignificant as determined by Duncan's multiple comparison test at the .05 level.

To determine a taxonomy of exercise, the results of Duncan's test on the combined means was used. The dip created a significantly greater activity in the pectoralis major using the combined means of the segments than any of the five remaining exercises. The wide push-up and push-up would follow after the dip in order from high to low activity. The pull-up and chin-up would follow the two push-ups, and the sit-down push-up would finish the taxonomy. Since differences between the two push-ups and differences between the pull-up and chin-up were not significant at the .05 level, they were grouped in the final taxonomy. Therefore, a true taxonomy of individual exercises was not established, but groups of exercises could establish a progression for continued muscular development.

Results of One-Way Analysis of Variance of the Clavicular Electromyographic Activity

The analysis of the clavicular activity during exercises was based upon the digital display that represented the clavicular activity using electromyographic techniques. Differences of muscular activity did occur in the clavicular portion of the pectoralis major. (See Figure 11, p. 86.) The least activity was observed in the chin-up. The most activity occured in the dip. The remaining four exercises from low to high activity levels were the pull-up, sit-down push-up, push-up and wide push-up.

Two possible considerations may have explained why differences existed. First, different muscle groups may have assisted in the movement of the humerus to a varying degree. The latissimus dorsi may have deflated the activity output of the clavicular segment in the chin-up and pull-up because of the important role the latissimus dorsi plays in these exercises. The anterior deltoid may have influenced the activity of the clavicular segment of the pectoralis major because of the similar functions of the clavicular segment of the pectoralis major and anterior deltoid. The second

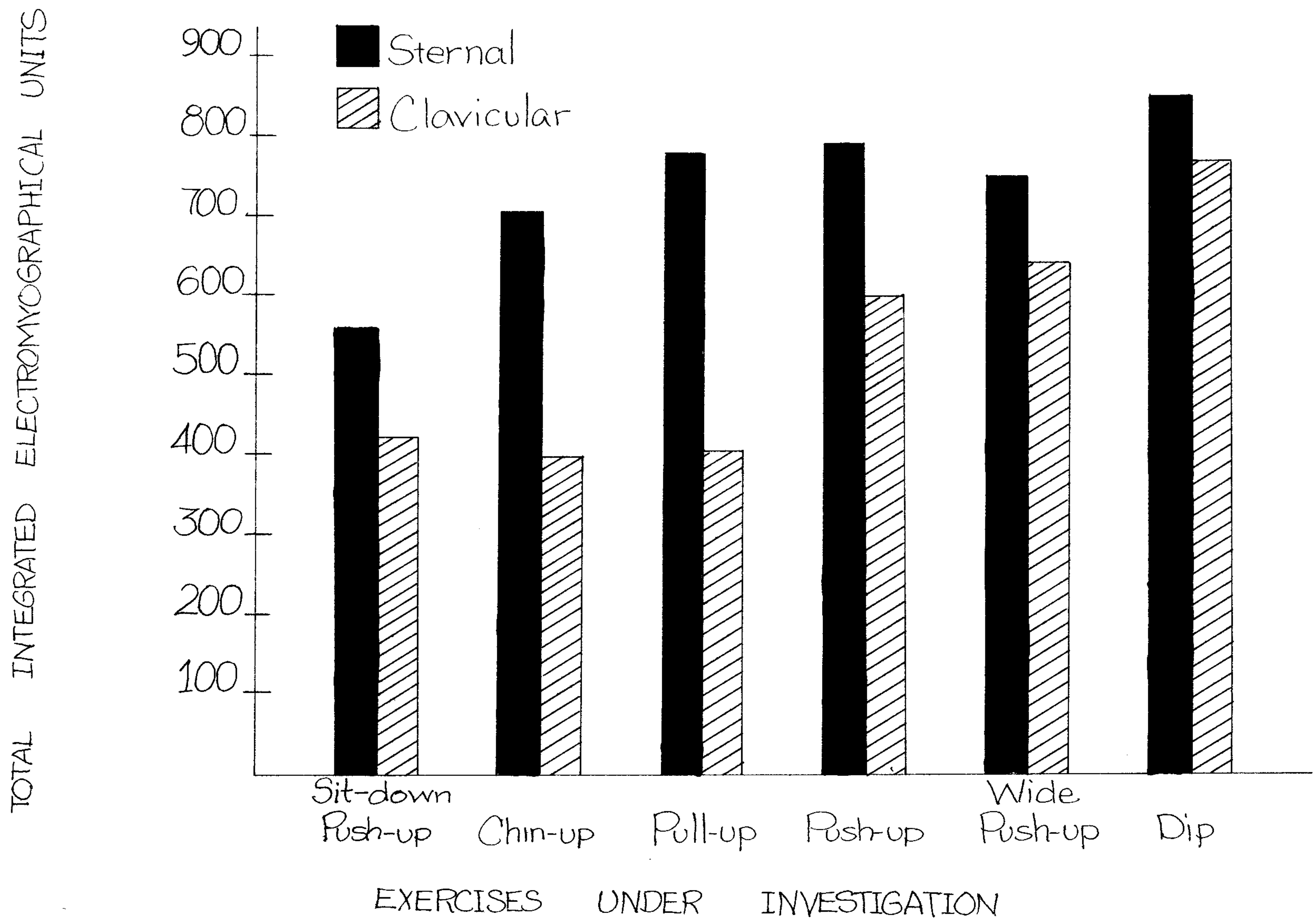

Fig. 11--Mean electromyographical activity of sternal and clavicular segments by exercise.

possible consideration for differences of activity occurring in the clavicular segment was the differences in resistance. While the pull-up, chin-up and dip required a subject's entire weight to be lifted, the two push-ups and the sit-down push-up required only a portion of a subject's total body weight to be lifted. The supporting function of a subject's feet influenced the resistance that had to be lifted. The length of the resistance arm where feet were used for support may have had an influence on clavicular segment activity. The sit-down push-up had a shorter resistance arm than the two push-ups. This shorter resistance arm would have required less force and thus, less muscular activity. The push-up, on the other hand, with its longer resistance arm would have required more muscle activity than the sit-down push-up.

The results of a one-way analysis of variance suggested that a statistical difference did exist in clavicular pectoralis major involvement during the selected exercises. An F- ratio of 13.657 was achieved and equaled a level of significance of .0001. The .05 level was chosen for acceptance or rejection. (See Table II, page 88.) Since the F-ratio was significant, Duncan's test for multiple comparison was used to establish where differences existed.

Duncan's Multiple Comparison of Clavicular Activity

The results of Duncan's multiple comparison test suggested that eleven of the fifteen possible paired comparisons

TABLE II

SUMMARY TABLE OF ONE-WAY ANALYSIS OF VARIANCE
FOR THE CLAVICULAR SEGMENT

Source	Sum of Squares	Degrees of Freedom	Variance Estimate	F-Ratio	Probability
Between	3557266	5	711453	13.657*	.0001
Within	9064162	174	52092	. . .	. . .
Total	12621428	179	. . .	. . .	. . .

were significant. (See Figure 12, page 89.) The dip displayed a significantly greater activity in the clavicular segment than any of the five other exercises under investigation. The wide push-up exhibited a greater activity in the clavicular portion than the chin-up, pull-up and sit-down push-up. The push-up demonstrated a significantly greater activity in the clavicular pectoralis major than the chin-up, pull-up and sit-down push-up. All other comparisons were insignificant.

The dip could have displayed greater activity in the clavicular segment than the chin-up and pull-up because of other muscular involvement. The latissimus dorsi is very active in the pull-up and chin-up and this activity could have been reflected in defined clavicular activity. The dip displayed greater activity in the clavicular segment than the sit-down push-up. It was possible the support of a portion of each subject's weight by his feet reduced the

	Chin-Up	Pull-Up	Sit-Down Push-Up	Push-Up	Wide Push-Up	Dip
Chin-Up	. .	115.51	121.59	125.72*	128.72*	131.10*
Pull-Up	. .	. .	115.51	121.59*	125.72*	128.72*
Sit-Down Push-Up	. .	. .	. .	115.51*	121.59*	125.72*
Push-Up	. .	. .	. .	. .	115.51	121.59*
Wide Push-Up	. .	. .	. .	. .	. .	115.51*
Dip	. .	. .	. .	. .	. .	. .

* = .05 level.

Fig. 12--Matrix of Duncan's multiple comparison of clavicular activity.

resistance. The reduction in resistance could have been reflected in lower activity of the clavicular pectoralis major because of the reduced force needed to complete the exercise. The dip showed a greater activity in the clavicular segment than either of the two push-ups under investigation. Two possible explanations could have been involved. First, there could have been a lowered resistance in the push-ups because of the support function of the feet. A second consideration was the fact that the anterior deltoid could have shared in the clavicular segment's function of humerus rotation while executing the two push-ups. Either or both of the above possibilities could have been the cause for differences in the dip and two push-ups.

The wide push-up displayed a greater activity in the clavicular portion than the chin-up and pull-up. A possible explanation for the difference would have been the involvement of the latissimus dorsi. The latissimus dorsi is very active in the chin-up and pull-up. The wide push-up also demonstrated a greater activity in the clavicular pectoralis major than the sit-down push-up. The fact that the wide push-up had a greater resistance arm and then required more force than the sit-down push-up may have been reflected in the lower clavicular segment activity during the sit-down push-up.

The push-up displayed greater activity in the clavicular portion of the pectoralis major than the chin-up or pull-up.

The involvement of the latissimus dorsi could have been reflected in the lower activity during the chin-up and pull-up. The push-up exhibited greater activity than the sit-down push-up in the clavicular portion of the pectoralis major. The shortened resistance arm of the sit-down push-up may have resulted in less activity displayed than in the push-up.

Means did differ in the other comparisons. None of these differences could be accepted at the .05 level of significance. Therefore, all other comparisons are insignificant and any difference that did exist could have been subject to chance.

Results of One-Way Analysis of Variance of the Sternal Pectoralis Major

The analysis of the sternal activity during exercises was based upon the digital display that represented the sternal activity using electromyographic techniques. The results of the one-way analysis of variance revealed that differences did exist in the sternal segment between exercises. These differences may result from three possible explanations. First, other muscle groups may have been active to a varying degree while executing the selected exercises. The influence of other muscle groups would have influenced the sternal portion's activity. The second consideration that may have influenced the sternal segment's activity was the difference in resistance that the humerus had to overcome. Each subject's body weight was used as a control, therefore, the resistance would not have been equal between exercises. The dip, pull-up and chin-up placed a subject's weight upon his arms. Thus each subject's total weight was lifted. In the case of the two selected push-ups and the sit-down push-up, some of the subject's weight was supported by his feet. Thus the force needed to lift the subject would not have been as great. Sternal pectoralis major involvement may have reflected the difference in resistance. The third consideration for the differences would have been the range of motion of the humerus. During the chin-up and pull-up the humerus was rotated through a 180 degree arc. During the dip and the two push-ups, the humerus traveled approximately 90 degrees. Differences may have occurred because of the variance in ranges of motion.

The dip created the most activity in the sternal portion of the pectoralis major. (See Figure 11, page 86). The least activity was observed in the sit-down push-up. The order of the four remaining exercises from lowest to highest activity was the chin-up, pull-up, wide push-up and push-up.

The .05 level of significance was achieved and suggested that a real difference did exist. A probability of .0002 was achieved for the F-ratio of 5.197 with the indicated degrees of freedom. (See Table III, page 93.) Since the F-ratio was significant, Duncan's multiple comparison test was used to analyze where the differences existed among the fifteen possible paired comparisons.

TABLE III

SUMMARY TABLE OF ONE-WAY ANALYSIS OF VARIANCE FOR THE STERNAL SEGMENT

Source	Sum of Squares	Degrees of Freedom	Variance Estimate	F-Ratio	Probability
Between	1543630	5	308726	5.197	.0002
Within	10335683	174	59400	. . .	. . .
Total	11879313	179	. . .	. . .	. . .

Duncan's Multiple Comparison of Sternal Activity

Results of Duncan's multiple comparison test indicated differences existing in six of the fifteen comparisons. (See Figure 13, page 94.) The sit-down push-up displayed significantly less activity in the sternal portion of the pectoralis major than the five other exercises. The low activity in the sternal segment suggested that the training effect of the sit-down push-up for sternal development was negligible.

The dip displayed significantly greater activity in the sternal pectoralis major than the sit-down push-up. Both of these exercises were designed so that the range of the humerus was a 90 degree arc. Therefore, range of movement would not explain the difference. The difference may have been attributable to the increased resistance that had to be overcome during the execution of the dip. The feet served a supportive function during the sit-down push-up and that would have reduced the resistance necessary to overcome gravity.

	Sit-Down Push-Up	Chin-Up	Wide Push-Up	Pull-Up	Push-Up	Dip
Sit-Down Push-Up	. .	123.35*	129.84*	134.25*	137.45*	139.99*
Chin-Up	. .	. .	123.35	129.84	134.25	137.45*
Wide Push-Up	. .	. .	. .	123.35	129.84	134.25
Pull-Up	. .	. .	. .	. .	123.35	129.84
Push-Up	. .	. .	. .	. .	. .	123.35
Dip	. .	. .	. .	. .	. .	. .

* = .05 level.

Fig. 13--Matrix of Duncan's multiple comparison of sternal segment electromyographic activity.

The dip also displayed a significantly greater activity in the sternal segment than the chin-up. The reduced activity from the chin-up may have been attributable to the involvement of the latissimus dorsi.

The push-up demonstrated a significantly greater activity in the sternal segment than the sit-down push-up. The push-up and the sit-down push-up were partially supported by the feet. The difference could have been due to the length of the resistance arm. The resistance arm for the push-up was much larger than the sit-down push-up. Therefore, more force would have been needed to execute the push-up. The need for greater force could have been attributable to the sternal pectoralis major.

The pull-up exhibited significantly greater activity in the sternal portion than the sit-down push-up. The pull-up requires the lifting of a subject's total body weight while the sit-down push-up allows for part of the subject's weight to be supported by his feet. The difference in resistance could have been reflected in sternal pectoralis major involvement.

The wide push-up displayed significantly greater activity in the sternal pectoralis major than the sit-down push-up. The difference could have existed because of the same phenomenon as the regular push-up. The resistance arm is greater in the wide push-up than in the sit-down push-up. The increased resistance arm would have required more force;

and therefore, involvement of the sternal portion of the pectoralis major would have been greater in the wide push-up.

The chin-up in contrast to the sit-down push-up exhibited a significantly greater activity in the sternal pectoralis major. The difference may have been caused by the unequal resistance that had to be overcome. The chin-up could have produced more activity in the sternal segment because of the chin-up's greater resistance.

The results of Duncan's multiple comparison test on sternal activity revealed differences between the sit-down push-up and the five other exercises under investigation. Also the dip displayed a significantly greater activity than the chin-up, all other comparisons were insignificant.

Discussion of the Findings

The investigation of the pectoralis major was developed within the confines of the expressed purposes and hypotheses. The data collected from the procedures developed were analyzed and the results were found to give credence to acceptance or rejection of the stated hypotheses. The statistical treatments of the data reflect the purposes of the study and implications were drawn.

The first purpose of the study was to determine if there was any mean group differences of pectoralis major activity attributable to the selected exercises. It was hypothesized that significant differences would exist.

Results of the two-way analysis of variance confirmed that pectoralis major activity differed among the selected exercises. Therefore, when prescribing developmental exercises for the pectoralis major, a taxonomy of reported exercises would allow successive progressive resistance exercises to be established. (See Appendix D.) For muscular development to enhance sports skills or for rehabilitation purposes, the taxonomy of exercises based upon an object measure would suggest a logical progression.

The second purpose of the study was to ascertain if differences of activity level existed between the two segments of the pectoralis major. It was hypothesized that the clavicular portion would exhibit a significantly greater activity than the sternal portion. The results of statistical treatments on the electromyographic activity of the sternal and clavicular segments of the pectoralis major suggested that the sternal segment exhibited significantly greater activity than the clavicular portion. The inference suggested was that the sternal segment of the pectoralis major had significantly greater activity, thus muscular activity, in the observed exercises.

The third purpose of the investigation was to ascertain if interaction between segments and exercises was demonstrated. It was hypothesized that interaction would be significant. Results of the two-way analysis of variance suggested that interaction between the exercises and segments was significant. Duncan's test for multiple comparisons determined where differences existed. Thus, the six exercises could be ranked according to established differences, and a taxonomy of exercises for the development of the pectoralis major was developed.

A hypothesis stating that the dip would produce significantly greater activity in the clavicular portion than the five other exercises was proposed. Based upon the results of a one-way analysis of variance and Duncan's multiple comparison test, the dip did yield greater activity in the clavicular segment than the remaining five exercises. If development of the clavicular segment for sports skills or rehabilitation was needed, the dip would be the best exercise of the six exercises investigated.

A hypothesis suggesting that the pull-up would produce greater activity than the other five exercises under investigation was proposed. The results of a one-way analysis of variance and Duncan's test for multiple comparison did not support the above hypothesis. No single exercise created significantly greater activity in the sternal segment of the pectoralis major than the other five exercises under investigation. The sit-down push-up created significantly less activity in the sternal segment than the other five exercises. For production of muscular development of the sternal segment all exercises except the sit-down push-up could be utilized. One other comparison was significant, the dip displayed greater activity than the chin-up in the sternal segment. Thus, for muscular developmental purposes, the dip when compared to the chin-up, would have a greater training effect.

The fourth purpose of the investigation was to ascertain if a progression of exercises could be established. It was hypothesized that an order effect in terms of pectoralis major activity among the selected exercises could be established. The results of Duncan's test upon the combined mean of the pectoralis major during the six exercises suggest that exercises can be grouped based upon significant differences among the multiple comparisons. A rank order based upon means can be established, but a taxonomy where significant differences occur between each comparison was not found. A taxonomy based upon groups of exercises was possible, but not for individual exercises.

A strong case could be suggested for the dip being the best exercise of those studied for pectoralis major development. When means of the sternal and clavicular segment were combined, the dip yielded significantly greater activity than the other exercises under investigation. When comparing exercises for the clavicular segment development, the dip revealed significantly greater activity than the five other exercises. The means of the combined segments, and the clavicular segment were greater in the dip when compared to the five other exercises under investigation. The mean score of the dip in the sternal segment analysis was not significantly greater than the other exercises, but was numerically greater.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

The problem of this investigation was the analysis of the pectoralis major comparing six selected antigravity exercises using electromyographic techniques. The six exercises have been suggested by authorities to develop the pectoralis major. An assumption was made that surface electromyography is a valid technique for measuring muscular activity.

The purposes of this study were to answer the following questions.

1. Is there any mean group difference of pectoralis major activity attributable to the selected exercises?

2. Is there any mean group difference attributable to the observed portions of the pectoralis major?

3. Is there any mean group differences attributable to interaction of exercise types and observed portions of the pectoralis major?

4. Is it possible to establish a progression of the observed exercises from low to high activity levels?

The procedure for collecting data included selection of the sample, research design, testing procedures, and procedures for treating the data. An incidental sample of thirty male students enrolled in physical education classes during the Spring of 1976 was utilized in the investigation. These subjects were screened to determine if they could perform the exercises, and if they could perform the exercises at the cadence established by the investigation. The research design of the investigation was a split-plot factorial design with repeated measures of the sternal and clavicular electromyographic activity repeated over the six exercises. Treatments for each subject were randomized to eliminate an order effect that could contaminate the data. The skin preparation procedures to lower skin resistance to 5,000 ohms were used for each subject. After skin preparation, a bipolar lead system was utilized to maintain the sternal and clavicular segments of the pectoralis major. The electrical activity was integrated and displayed on Hewlett-Packard digital systems. The numerical score represention of muscular activity was used for the dependent variable in the statistical analyses. Five minute rest periods between exercises was utilized to control for fatigue and when interaction was determined to be significant, Duncan's test for multiple comparisons was utilized. A one-way analysis of variance and Duncan's multiple comparison test was performed on each segment of the pectoralis major over the six exercises. The .05 level of significance was utilized for determination of significance for all statistical treatments.

Results of the two-way analysis of variance confirmed that significant differences did occur among the exercises. A significantly greater activity was also observed in the sternal portion of the pectoralis major compared to the activity in the clavicular segment. The interaction of segments and exercises was also determined to be significant.

Duncan's multiple comparison test was used to determine where differences existed among paired comparisons of exercises using combined means of the sternal and clavicular segment activity. Results of Duncan's test revealed several significant differences. The dip demonstrated significantly greater activity than any of the other exercises. The wide push-up demonstrated significantly greater activity than the sit-down push-up, chin-up and pull-up. The push-up demonstrated significantly greater activity than the sit-down push-up. All other comparisons were insignificant.

Results of a one-way analysis of variance upon the clavicular segment also revealed significant differences. Duncan's test for multiple comparisons revealed where differences in clavicular activity existed among the exercises. The dip exhibited significantly greater activity than the five other exercises under investigation. The wide push-up revealed significantly greater activity in the clavicular segment than the chin-up, pull-up, and sit-down push-up. The push-up indicated significantly greater clavicular activity than the pull-up, chin-up, sit-down push-up. All other comparisons were insignificant.

Results of a one-way analysis of variance confirmed that sternal pectoralis major activity varied significantly among the exercises. Duncan's test for multiple comparisons suggested that the sit-down push-up displayed significantly less activity in the sternal segment compared to the five other exercises. The dip displayed a significantly greater activity in the sternal segment than the chin-up. All other comparisons were insignificant.

Conclusions

Based upon the procedures utilized for data collection, the statistical treatments of that data, the limitations and major findings of the study, the following conclusions merit consideration.

1. A difference in pectoralis major activity is evidenced among the exercises under investigation.

2. The sternal segment of the pectoralis major displays greater electromyographic activity than the clavicular portion when observing the exercises under investigation.

3. A significant interaction effect is evidenced between the exercises under investigation and the clavicular and sternal pectoralis major.

4. The dip produces greater electromyographic activity in the clavicular portion of the pectoralis major than any other exercise under investigation.

5. The pull-up did not display a difference in electromyographic activity in the sternal segment of the pectoralis major against all other exercises under investigation.

6. A ranking effect of the pectoralis major activity is possible by single exercise or grouped orders. The order of difficulty of exercises proceeds in this manner from the highest activity level: the dip, the wide push-up and push-up, the pull-up and chin-up, and the sit-down push-up.

Recommendations

During the development of the investigation, several problem areas were observed that lend themselves to further investigations.

1. Other calisthenics purported to develop the pectoralis major activity need to be analyzed in conjunction with the six observed exercises.

2. Exercises that use progressive resistance equipment purported to develop the pectoralis major need to be analyzed.

3. Large superficial muscles and muscle groups need to be analyzed with surface electromyography to establish taxonomies of exercises for muscular development.

4. Sports skills that utilize the pectoralis major have not been exhaustively analyzed. Anatomical analyses of sports skills would lead to greater understanding of the observed sports skills.

5. The time needed during rest periods to control for fatigue artifacts would aid in substantiating electromyographic procedures.

APPENDIX

APPENDIX A

North Texas State University--Form 2

Use of Human Subjects

Informed consent.

Name of Subject____

1. I hereby give consent to ____________________________ to perform or supervise the following investigational procedure or treatment. Placement of Bipolar surface electrodes over the two motor points of the pectoralis major. One trial of each exercise will be performed with five minutes of rest between exercises. The exercises to be performed are the push-up, pull-up, chin-up, sit-down push-up, wide push-up and dip.

2. I have (seen, heard) a clear explanation and understand the nature and purpose of the procedure or treatment: possible appropriate alternative procedures that would be advantageous to me (him, her): and the attendant discomforts or risks involved and the possibility of complications which might arise. I have (seen, heard) a clear explanation, and understand the benefits to be expected. I understand that the procedure or treatment to be performed is investigational and that I may withdraw my consent for my (his, her) status. With my understanding of this, having received this information and satisfactory answers to the questions I have asked, I voluntarily consent to the procedure designated in Paragraph 1 above.

____
Date

Signed:__________________ Signed: ________________________
Subject
or

Signed:__________________

Signed: ________________________
Person Responsible

____
Relationship

Instructions to persons authorized to sign:
If the subject is not competent, the person responsible shall be the legal appointed guardian or legally authorized representative.
If the subject is a minor under 18 years of age, the person responsible is the mother or father or legally appointed guardian.
If the subject is unable to write his name, the following is legally acceptable: John H. (His X mark) Doe and two (2) witnesses.

APPENDIX B

Research and Investigation Involving Humans

Statement by Program Director and
Approved by Department Chairman

This abreviated form is designed for describing proposed programs in which there is justifiable minimal risk to human participants, If any member of the Human Research Review Committee should require more information, the investigator will be so notified. Six copies of this form should be submitted to the committee chairman.

Title of Study: Electromyographic Analysis of the Pectoralis Major During Six Selected Antigravity Calisthenics

Program Directors: Dr. Marilyn Hinson
Russell D. Fischer

Estimated beginning date of study. 3/22/76 Estimated duration: 2 weeks

Brief description of study (use additional pages or attachments, if desired, and include the approximate number and ages of participants):

The general purpose of the proposed investigation is to analyze, through electromyography, the pectoralis major during selected exercises. The subjects will be thirty volunteer men between the ages of nineteen and twenty-five who are able to perform the exercises.

1. What are the potential risks to the human subjects involved in this research or investigation?

There are no potential risks that I am aware of since the exercises to be executed are not injurous because of execution or position.

2. Outline the steps taken to protect the rights and welfare of the individuals involved:

The subjects will be told to do the six exercises. Only one trial of each exercise will be performed making a total of six performances. The subjects will rest five minutes between exercises. Exercises will be performed at the Biomechanics Lab at Texas Woman's University.

3. Outline the method for obtaining informed consent from the subjects or from the person legally responsible for the subjects. (Attach documents, i.e., a specimen informed consent letter).

See attached Informed Consent Form

4. If the proposed study included the administration of personality tests, inventories, or questionnaires, indicate how the subjects are given the opportunity to express their willingness to participate. If the subjects are less than the age of legal consent, or mentally incapacitated, indicate how consent of parents, guardians, or other qualified representatives will be obtained:

(Signed) ______________________________ __________
Program Director Date

(Signed) ______________________________ __________
Dean, Department Head or Director Date

Date received by committee chairman: ______________

TEXAS WOMAN'S UNIVERSITY--FORM 2

USE OF HUMAN SUBJECTS

INFORMED CONSENT

Name of Subject: ______________________________

1. I hereby give consent to ______________________ to perform or supervise the following investigational procedure or treatment. Placement of Bipolar surface electrodes over the two motor points of the pectoralis major. One trial of each exercise will be performed with five minutes of rest between exercises. The exercises to be performed are the push-up, pull-up, chin-up, sit-down push-up, wide push-up, and dip.

2. I have (seen, heard) a clear explanation and understand the nature and purpose of the procedure or treatment: possible appropriate alternative procedures that would be advantageous to me (him, her): and the attendant discomforts or risks involved and the possibility of complications which might arise. I have (seen, heard) a clear explanation and understand the benefits to be expected. I understand that the procedure or treatment to be performed is investigational and that I may withdraw my consent for my (his, her) status. With my understanding of this, having received this information and satisfactory answers to the questions I have asked, I voluntarily consent to the procedure or treatment designated in Paragraph 1 above.

____
Date

Signed: ______________________ Signed: ______________________
Subject

or

Signed: ______________________ Signed: ______________________
Person Responsible

____
Relationship

Instructions to persons authorized to sign:
If the subject is not competent, the person responsible shall be the legal appointed guardian or legally authorized representative.
If the subject is a minor under 18 years of age, the person responsible is the mother or father or legally appointed guardian. If the subject is unable to write his name, the following is legally acceptable: John H (His X mark) Doe and two (2) witnesses.

APPENDIX C

Data Sheet

Name:______________________________________ Date:______________

Ht.______inches

Wt.______lbs

age______years/months

Exercises

Order			Sternal	Clavicular
______	1.	Dip	______	______
______	2.	Chin-up	______	______
______	3.	Pull-up	______	______
______	4.	Push-up	______	______
______	5.	Sit-down Push-up	______	______
______	6.	Wide Push-up	______	______

APPENDIX D

Rank Order of Exercises Based Upon Electomyographic Activity of the Pectoralis Major

Combined Means			Clavicular			Sternal		
Order	Exercise	Mean Activity	Order	Exercise	Mean Activity	Order	Exercise	Mean Activity
1	Sit-down Push-up	490.18	1	Chin-up	398.43	1	Sit-down Push-up	557.77
2	Chin-up	551.98	2	Pull-up	408.23	2	Chin-up	705.53
3	Pull-up	595.97	3	Sit-down Push-up	422.60	3	Wide Push-up	751.90
4	Push-up	695.75	4	Push-up	601.13	4	Pull-up	783.70
5	Wide Push-up	697.62	5	Wide Push-up	643.33	5	Push-up	790.37
6	Dip	810.92	6	Dip	770.17	6	Dip	851.67
Standard Deviation	=	261.58	Standard Deviation	=	265.54	Standard Deviation	=	257.61

BIBLIOGRAPHY

Books

Arnheim, Daniel D., David Auxter and Walter C. Crowe, Principles and Methods of Adapted Physical Education, 2nd ed., St. Louis, C. V. Mosby Co., 1973.

Basmajian, John V., Muscles Alive: Their Function Revealed by Electromyography, Baltimore, Maryland, The Williams and Wilkens Co., 1967.

Clarke, David H. and H. Harrison Clarke, Research Processes in Physical Education, Recreation and Health, Englewood Cliffs, New Jersey, Prentice-Hall, Inc., 1970.

Daniels, Lucille, Marian Williams and Catherine Worthingam, Muscle Testing, 2nd ed., Philadelphia, W. B. Saunders Co., 1956.

Falls, H. B., E. L. Wallis and G. A. Logan, Foundations of Conditioning, New York, Academic Press, 1970.

Golding, Lawrence A. and Ronald R. Bos, Scientific Foundation of Physical Fitness Programs, 2nd ed., Minneapolis, Burgess Publishing Co., 1970.

Sorani, Robert, Circuit Training, Dubuque, Wm. C. Brown, Co., 1966.

Thompson, Clem W., Manual of Structural Kinesiology, 6th ed., St. Louis, C. V. Mosby Co., 1969.

Wells, Katherine F., Kinesiology, 5th ed., Philadelphia, W.B. Saunders Co., 1971.

Articles

Adrian, Marlene, "Cinematographic, Electromyographic and Electro-goniometric Techniques for Analyzing Human Movements," Exercise and Sport Sciences Reviews, edited by Jack H. Wilmore, New York, Academic Press, 1973.

Basmajian, John V., "Electromyographic Analyses of Basic Movement Patterns," Exercise and Sport Sciences Reviews, edited by Jack N. Wilmore, New York, Academic Press, 1973.

Basmajian, John V., and F. J. Bazant, "Factors Preventing Downward Dislocation of the Adducted Shoulder Joint," Journal of Bone and Joint Surgery, XLI (October, 1957), 1182-1186.

____________________ and R. Elkus, "Endurance in Hanging by the Hands," American Journal of Physical Medicine, LII (June, 1973), 124-127.

Bearn, J. G., "An Electromyographic Study of the Trapezius, Deltoid, Pectoralis Major, Biceps and Triceps Muscles During Static Loading of the Upper Limb," The Anatomical Record, CXL (June, 1961), 103-107.

Bierman, William and Leonard J. Yamshon, "Electromyography in Kinesiologic Evaluations," Archives of Physical Medicine, XXIX (March, 1948), 206-211.

Bigland, Brenad and O. C. J. Lippold, "The Relation Between Force, Velocity and Integrated Electrical Activity in Human Muscles," Journal of Physiology, CXXIII (January, 1954), 214-224.

Darcus, M. D. and Nancy Salter, "Amplitude of Pronation and Supination," Journal of Anatomy, LXXVII (April, 1953), 169-184.

Dempster, Wilfrid T., "Mechanisms of Shoulder Movement," Archives of Physical Medicine and Rehabilitation, XLVI (January, 1965), 49-70.

Gutin, Bernard and Stanley Lipetz, "An Electromyographic Investigation of the Rectus Abdominus in Abdominal Exercises," Research Quarterly, XLII (October, 1971), 256-263.

Hermann, George W., "An Electromyographic Study of Selected Muscles Involved in the Shot Put," Research Quarterly, XXXIII (March, 1962), 85-93.

Hinson, Marilyn M., "An Electromyographic Study of the Push-up for Women," Research Quarterly, XL (May, 1969), 305-311.

Inman, Verna T., J. B. Saunders, and LeRoy C. Abbot, "Observations on the Function of the Shoulder Joint," The Journal of Bone and Joint Surgery, XLII (January, 1944), 1-30.

Kamon, Eliezer, "Electromyographic Analysis of the Scissors Exercise Performed on the Pommel Horse," Journal of Sports Medicine, VI (December, 1966), 223-234.

_______________ "Electromyography of Static and Dynamic Postures of the Body Supported on the Arms," Journal of Applied Physiology, XXI (September, 1966), 1611-1618.

Kitzman, Eric W., "Baseball: Electromyographic Study of Batting Swing," Research Quarterly, XXXV (May, 1964), 166-178.

Lance, Brian M. and Don B. Chaffin, "The Effect of Prior Muscle Exertions on Simple Movements," Human Factors, XIII (August, 1971), 355-361.

Landa, Jean, "Shoulder Muscle Activity During Selected Skills on the Uneven Parallel Bars," Research Quarterly, XLV (May, 1964), 120-217.

Licht, Sidney, "History of Electrodiagnosis," Electrodiagnosis and Electromyography, 3rd ed., edited by Sidney Licht, Baltimore, Waverly Press, Inc., 1971.

Lippold, O. C. J., J. W. T. Redfearn, and J. Vuco, "The Relationship Between the Stretch Reflex and the Electrical and Mechanical Rhythmicity in Human Voluntary Muscle," Journal of Applied Physiology, CXXXVIII (July, 1957), 14p-15p.

____, "The Electromyography of Fatigue," Ergonimics, III (January, 1960), 121-131.

Lloyd, Andree J., "Surface Electromyography During Sustained Isometric Contractions," Journal of Applied Physiology, XXX (May, 1971), 713-719.

McCloy, C. H., "Some Notes on Differential Actions of Partite Muscles," Research Quarterly, XVII (December, 1946), 254-263.

Miles, Meryl, C. A. Martensen and W. E. Sulivan, "Electromyography During Normal Voluntary Movements," Anatomical Record, XCVIII (May-August, 1947), 209-218.

O'Connell, A. L. and E. B. Gardner, "The Use of Electromyography in Kinesiological Research," Research Quarterly, XXVIV (May, 1963), 166-184.

Partridge, Lloyd and Frances Huber, "Factors in the Interpretation of the Electromyogram Based on Muscle Response to Dynamic Nerve Signals," American Journal of Physical Medicine, XLVI (December, 1967), 1276-1289.

Scheving, Lawrence E. and John E. Pauly, "An Electromyographic Study of Some Muscles Acting on the Upper Extremity of Man," The Anatomical Record, CXXXV (December, 1959), 239-245.

Shambes, Georgia M. and Joan C. Waterland, "Control of Motor Units in Skill and Postural Muscles in Normal Man," American Journal of Physical Medicine, LII (June, 1973), 114-123.

Shevlin, Geraldine M. Justus F. Lehmann, and Jennie A. Lucci, "Electromyographic Study of the Function of Some Muscles Crossing the Glenohumeral Joint," Archives of Physical Medicine, L (May, 1969), 264-270.

Sigerseth, P. C. and C. N. McCloy, "Electromyographic Study of Selected Muscles Involved in Movements of Upper Arm of Scapulohumeral Joint," Research Quarterly, XXVII (December, 1956), 409-417.

Slater-Hammel, Arthur T., "Action Current Study of Contraction-Movement Relationships in Golf Stroke," Research Quarterly, XIX (December, 1948), 164-176.

________________________, "An Action Current Study of Contraction-Movement Relationships in the Tennis Stroke," Research Quarterly, XX (December, 1949), 424-431.

Slaughter, Duane R., "Electromyographic Studies of Arm Movements," Research Quarterly, XXX (October, 1959), 326-337.

Stetson, R. N. and H. D. Bouman, "The Action-Current as Measure of Muscle Contraction," Science, LXXVII (February, 1933), 219-221.

Wilcott, R. C. and H. G. Beenken, "Relation of Integrated Surface Electromyography and Muscle Tension," Perceptual and Motor Skills, VII (December, 1957), 295-298.

Unpublished Materials

Anderson, Jean P., "An Electromyographic Study of Ballistic Movement in the Tennis Forehand Drive," unpublished doctoral dissertation, Department of Physical Education, University of Minnesota, 1970.

Crase, Leonard W., "A Study of Movements at the Humero-scapular, the Acromioclavicular and the Sterno-clavicular Joints," unpublished master's thesis, Department of Physical Education for Men, University of Iowa, Iowa City, Iowa, 1950.

Finanger, Kenton E., "An Electromyographic Study of the Function of Selected Muscles Involved in the Throwing of the Discus," unpublished doctoral dissertation, Department of Physical Education for Men, University of Iowa, Iowa City, Iowa, 1969.

Garrison, Levon E., "Electromyographic-Cinematographic Study of Muscular Activity During the Golf Swing," unpublished doctoral dissertation, Department of Physical Education, Florida State University, Gainesville, Florida, 1963.

Hallet, Charles D., "An Electromyographic Comparison of Muscular Activity for the Sternocostal Pectoralis Major, and Latissimus Dorsi in Three Cross Hold Positions," unpublished master's thesis, Department of Physical Education, Western Illinois University, 1971.

Harding, Linda T., "An Electromyographic Study of Selected Arm Support Activities," unpublished master's thesis, Department of Physical Education for Women, University of Iowa, Iowa City, Iowa, 1967.

Mapes, Donald F., "Electromyographic Study of Functions of Selected Muscles in: Check Action, Ballistic Movement and Follow-Through During the Baseball Throw," unpublished doctoral dissertation, Department of Physical Education for Men, University of Iowa, Iowa City, Iowa, 1964.

Randall, Nellie G., "An Electromyographic Study of Selected Muscles Involved in Two Methods of Chinning," unpublished doctoral dissertation, Department of Physical Education for Women, University of Iowa, Iowa City, Iowa, 1963.

Rice, Mary Agnes, "An Electromyographic Study of Specific Muscles Involved in the LaCrosse Cradle," unpublished doctoral dissertation, Department of Physical Education, Temple University, Philadelphia, 1969.

Santomier, James P., "An Electromyographic Analysis of Specific Muscles Used in Performing Selected Isotonic Weight Training Activities," unpublished doctoral dissertaion, College of Health, Physical Education and Recreation, University of Utah, Salt Lake City, Utah, 1971.