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To the Graduate Council:

I am submitting herewith a thesis written by Virginia Jean Lenz, entitled "An Electromyographic Investigation of the Biceps Brachii." I recommend that it be accepted in partial fulfillment for the degree of Master of Science, with a major in Physical Education.

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AN ELECTROMYOGRAPHIC INVESTIGATION OF THE BICEPS BRACHII

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Virginia Jean Lenz

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ABSTRACT

The purpose of this study was to investigate the functions of the biceps brachii through the use of fine-wire electrodes. Electrical activity of the biceps brachii was recorded during flexion of the lower arm; adduction of the arm; flexion of the upper arm; and flexion of the upper arm from the extended position.

Fine-wire-electrodes were inserted into the short and long head of the biceps brachii. Integrated recordings were obtained on a Model 7P3-D Electromyograph calibrated to yield a one centimeter pen deflection per 200 micro volt input. These recordings were qualitatively evaluated on the following scale:

Grade	Description
0	No activity to trace activity--highest pen deflection did not exceed .5 centimeters.
1	Light activity--highest pen deflection was between .5 centimeters and 1.5 centimeters.
2	Moderate activity--highest pen deflection was between 1.5 centimeters and 3.0 centimeters.
3	Heavy activity--highest pen deflection exceeded 3.0 centimeters.

Results showed that the biceps brachii was a flexor of the lower arm and upper arm and adductor of the arm. The biceps were most effective during movements in the supinated rather than the pronated position.

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CHAPTER I

INTRODUCTION

"Man has shown a continuing curiosity about the function and control of skeletal muscle" (3, p. 603). Scientists such as Galvani contributed great ideas to the field of electromyography. It was his belief that muscles actually stored and discharged electricity that was received from the nerves (3, p. 603). "Muscle electricity remained a scientific curiosity until the twentieth century when improved methods of detecting and recording minute electrical discharges of muscles became available" (3, p. 603).

Much of the pioneer work in this science was achieved through two English physiologists by the name of Adrian and Bronk. Next, came the first study to receive widespread notoriety which was the investigation done by Inman, et al studying the shoulder region movements. It was in the 1950's that electromyography was used in kinesiological studies and this was a great innovation (3, p. 603). In recent years, electromyography has been prompted on to more refined techniques by such researchers as J. V. Basmajian and J. T. Chamberland along with many others.

Electromyography has precipitated from the principle that contracting muscles produce a detectable current or voltage (5, p. 3). The use of electromyographic equipment permits us to study this principle in greater depth. The use of fine-wire electrodes over other

available means can be explained through the inherent ability to more accurately read impulses being received directly from the desired muscle.

I. STATEMENT OF THE PROBLEM

The purpose of this study was to investigate the functions of the biceps brachii in regard to its two component parts--the long head and the short head. This was designed to be accomplished through the use of fine-wire electrodes. The electrical activity of the muscle was recorded during the following movements: flexion of the lower arm; adduction; and flexion of the upper arm.

II. VALUE OF THE STUDY

While the actual functions of most skeletal muscles have been firmly defined, this does not hold true for the biceps brachii in regard to the separate heads. Anatomy textbooks vary in their descriptions as to what the long and short heads do individually.

Most studies involving the biceps brachii refer to it as an entire unit and the relevant studies are treated as such. There was need for electromyographic investigations of the biceps brachii and its component parts. Because of the innovation of working with the long and short head of the biceps, the investigator attempted to establish the basic functions of this muscle and its parts through the utilization of fine-wire electrodes.

III. ASSUMPTIONS AND LIMITATIONS

The following assumptions and limitations will apply to this study and should be seriously considered in this investigation:

1. The subjects used in this study will all be volunteers.
2. The techniques utilized by the subjects will require no special training other than following directions.
3. The age, sex, and physical condition of the subjects has no effect on this study.
4. The reliability and validity of the electromyographic recording equipment used cannot be verified beyond the guarantees procured from the company as well as careful calibration before and after each testing session.
5. The fine-wire electrodes are precise in the pick-up of the electrical activity of the muscle into which they are inserted.
6. Integrated recording data can be qualitatively evaluated as the function of a particular muscle in a specified movement.

CHAPTER II

REVIEW OF RELATED LITERATURE

This review of related literature was done with two specific areas in mind: (1) the description of the biceps brachii as presented by some anatomy textbooks, and (2) the literature pertaining to electromyographic investigations of the biceps brachii.

The biceps brachii is a long, fusiform muscle which is located on the front of the arm and divides into two heads from where it has received its name (13, p. 427). The functions of this muscle have been defined by several anatomists and electromyographic investigators. There is disagreement among authorities as to the true function of the biceps brachii in the pronation or semipronation process.

Basmajian and Latif stated that the biceps acts as a flexor of the elbow and acts best when the forearm is supinated. It acts less well in the semipronated position and not at all during the pronated position (8, p. 1106-1118). This is in agreement with Rasch and Burke who state that when the forearm is in a pronated position, the recorded electromyographic potentials from the biceps are lower than when the arm is situated in the supinated position (20, p. 228). This is also in agreement with Basmajian's opinion that the biceps work more efficiently during movements involving supination (6, p. 192). However some students have contended that when the arm is pronated the long head may

contract while the short head does not particularly indicate any signs of electrical activity.

Jacob and Francone state that the biceps brachii is responsible for flexing the upper arm and the forearm (16, p. 147). They also contend that the long head draws the humerus towards the glenoid fossa and aids in strengthening the shoulder joint (16, p. 147). This is in agreement with Anthony who states in more specified terms that the biceps brachii is active in the supinated movements of both the forearm and the arm. It also has some action in supinating the lower arm and hand (2, p. 139). Pansky and House point out that it is the long head which is responsible for the flexion of the upper arm and forearm (18, p. 198). Both heads of the biceps brachii are active in flexion of the shoulder and upper arm with the long head being the more active as stated by Basmajian (5, p. 165). This is agreed upon by Gardner, Gray, and O'Rahilly. They state that the biceps is a supinator of the forearm, and is active in flexion at the shoulder joint (12, p. 132).

It has been emphasized by a number of anatomy textbooks that the biceps brachii serve in stronger terms during resistance. Basmajian states that the biceps brachii is called into action to help flex the lower arm strongly against resistance or to supinate the forearm against resistance (5, p. 161). Some state that the biceps brachii is a supinator of the forearm and it does not act when the lower arm is extended against resistance.

The majority of electromyographic studies performed on the biceps brachii have been involved with the use of surface electrodes.

The remaining studies utilize the needle or fine-wire electrodes. There are a multitude of special electrodes that can be used (4, p. 112). This type of fine-wire electrode has gained wide acceptance because of its simplicity, flexibility, lack of discomfort, and good electrical pick-up (7, p. 1680). Essentially each electrode consists of a pair of extremely fine insulated wires placed in situ by means of a hypodermic needle which is then withdrawn while the wires remain in the muscle due to a bend at the end of implantation (9, p. 849). "The needle or fine-wire electrode condemns the exclusive use of surface electrodes in studies of fine movements, deep muscles, the presence or absence of activity in various postures, and, in short, in any circumstance where scientific precision is desirable" (4, p. 112). There is a lack of sufficient needle or fine-wire studies in electromyography since their utilization has only come about in the past several years.

Several studies have been done on the biceps brachii through the use of surface electrodes. Slaughter found that both heads of the biceps brachii aid the movements that require arm extension and forearm flexion (21, p. 326-337). Slaughter stated that action potentials recorded in these muscle parts are smaller at the end of the movement when the hand is pronated and are smaller at the start of the movement when the hand is being supinated. Kamon stated that the biceps activity was necessary most likely to prevent further forced pronation of the half pronated arm (17, p. 1614). Bearn's study involved the static loading of the arm. His results yielded that even with weights up to twenty-five pounds only initial activity occurred in a few subjects and

this subsided (10, p. 105). Basmajian discussed that the long head of the biceps generally shows more activity than the short head during slow flexion of the forearm, supination of forearm against resistance, and flexion of the shoulder joint (6, p. 170). Gregg, and others performed an electromyographic study using surface electrodes. They discovered that as extension of the right elbow occurs, biceps activity decreases precipitously, remains diminished until the 90 degree point occurs, and then increases again in activity as this muscle functions against the pull of gravity (14, p. 277). Sullivan, and others also performed some studies with surface electrodes. This group discovered that the most conspicuous increase in amplitude in the biceps occurred in the medial portion of the record when the movements were made with forearm supinated. The recording of a lower amplitude was present when the forearm was prone (22, p. 246). They also discovered that the amplitude was slightly greater for the long head, but the maximum was recorded from the short head with the forearm supine and an added load of 2.0 kg. (22, p. 248).

Four electromyographic studies have been done using intramuscular electrodes. The studies included the use of: (1) two concentric needles, (2) one coaxial needle, and (3) one fine-wire.

Basmajian and Latif used the concentric needle electrodes. They discovered that when flexion was performed slowly and without a load, the short head of the biceps acted only when the forearm was in the supine position. The short head of the biceps supinated the forearm when the elbow was in the extended position and strongly resisted in the

supine position (8, p. 1106-1118). It was found that the short head of the biceps was generally less active than the long head during the various movements.

Carlson and others performed a study using single coaxial needles to study the aging process in skeletal muscle. The average age of the subject was 82.5 years. Maximal Contraction was studied with the biceps brachii muscle contracting against manual resistance for twenty seconds (11, p. 143). In most subjects a decay in amplitude was observed after ten seconds. These findings were compared with those of a control study carried on in a similar manner on thirty young adults. The functions of the biceps brachii appeared to remain the same, but maximal contractions decreased with the elderly group.

Travill and Basmajian used concentric needle electrodes to study the supinators of the forearm. They found all movements of the forceful supination against resistance requires the cooperation of the biceps in various degrees (23, p. 559). With the elbow flexed or extended, the biceps was never active during pronation. Fast unresisted supination with the elbow flexed is assisted by the action of the biceps. However, when the elbow was held in the flexed position, the biceps showed a definite increase in action as shown in twelve of sixteen subjects.

Patton and Mortensen performed a study using intramuscular electrodes for the purpose of observing cocontractions (19, 255-268). Electrodes were inserted into the muscles of the right arm. One was placed in the long head of the biceps brachii, brachialis, and the triceps brachii. This study had the purpose of clarifying the role of the

antagonist muscle during flexion and extension of the forearm with and without an added load. It was discovered that during flexion, the subjects were unable to maintain cocontraction in the triceps in most attempts. During extension, the subjects were more successful in maintaining cocontraction of the flexor muscles. This agrees with previously cited opinions that the biceps rather than the triceps is the chief flexor of the upper arm and forearm.

CHAPTER III

PROCEDURES

The purpose of this chapter is to describe the procedures used in fulfilling the goals of this investigation. These procedures include: (1) the selection of the testing apparatus; (2) the selection of the subject; (3) the instruction of subjects; (4) the selection of tests; and (5) the treatment of data.

I. THE SELECTION OF TESTING APPARATUS

Several weeks prior to the actual collection of data, the investigator spent time learning to calibrate and operate the electromyographic equipment; to construct, sterilize, and insert bipolar, indwelling, fine-wire electrodes; and to evaluate and interpret the data accumulated.

Electromyographic Equipment

The basic piece of apparatus used in this investigation was a Model 7P3-D Electromyograph, manufactured by Grass Instrument Company, Quincy, Massachusetts. This equipment contains a four wide-band, direct-current preamplifier, four integrator units; four alternating current amplifiers; and four ink-writing oscillographs. The direct-writing oscillographs used were d'Arsenval galvonometers which produce a deflection of the pens proportional to the current which was produced and then

delivered by the driver amplifiers. The integrator unit produced a curved line which represented an average amplitude of raw data input.

Electrodes

Fine-wire electrodes of a bipolar nature were constructed and sterilized according to procedures designated by Basmajian and Stecko (9, p. 849). The fine-wire used is Karma alloy wire .025 mm in diameter and manufactured by Driver Harris Corporation, Harrison, New Jersey. The bipolar electrodes were inserted into the selected muscle through the use of standard hypodermic needles. The guage and length of the needle was 27 guage and 3/4 inch. The depth of the needle insertion varied respectively according to each individual subject's amount of subcutaneous tissue covering the biceps brachii.

Additional Equipment

The fine-wire bipolar electrodes were sterilized through the use of a Fisher Dry Heat Oven built by Fisher Scientific Company. A large padded table was used by subjects for proper arrangement of the supine position. Two weights were used in this study to act as resisting forces. The weights were five and ten pounds. The selection of the weights varied according to the sex and strength of the individual.

Testing Room

All the equipment was stored and operated in a thoroughly copper lined Faraday room which was specifically designed for electromyographic research.

II. SELECTION OF SUBJECTS

The subjects used in this electromyographic investigation were volunteers from the graduate student and teaching population of the Physical Education Department at the University of Tennessee. The number of subjects was limited to five individual subjects, two males and three females.

III. THE INSTRUCTION OF SUBJECTS

The subjects used in this investigation required no previous training. Each subject was instructed in the proper body mechanics for each specified movement. They were then permitted to practice the movements so as to allow for a smooth, steady rate of motion.

IV. SELECTION OF TESTS

The muscle was being studied in two segments--the long head and the short head. Both heads were tested simultaneously during the prescribed movements. The movements involved flexion of the lower arm executed three times unresisted as well as resisted. Adduction and the specified movements involving flexion of the upper arm were executed three times with resistance only. The movements in order of execution were as follows:

1. Flexion of the lower arm from the anatomical position to a 90 degree angle and return to original position without resistance.

2. Flexion of the lower arm from the anatomical position to a 90 degree angle and return to original position with resistance.
3. Flexion of the lower arm while pronated to a 90 degree angle and return to original position without resistance.
4. Flexion of the lower arm while pronated to a 90 degree angle and return to original position with resistance.
5. Adduction of the arm from a 45 degree angle to the body with resistance (manual resistance).
6. Flexion of the upper arm from the anatomical position to a 90 degree angle and return to original position with resistance.
7. Flexion of the upper arm from the pronated position to a 90 degree angle and return to original position with resistance.
8. Flexion of the upper arm from an extended position to a 90 degree angle and return with resistance.
9. Flexion of the upper arm from an extended position while the lower arm was in a pronated position to a 90 degree angle and return to original position with resistance.

The previously mentioned movements were executed while the subject was lying on his back supported completely by the padded table. The subject's arm was at his side for all starting positions except for the extended position. For the extended position, the subject's arm was completely supported by the investigator while in the starting position.

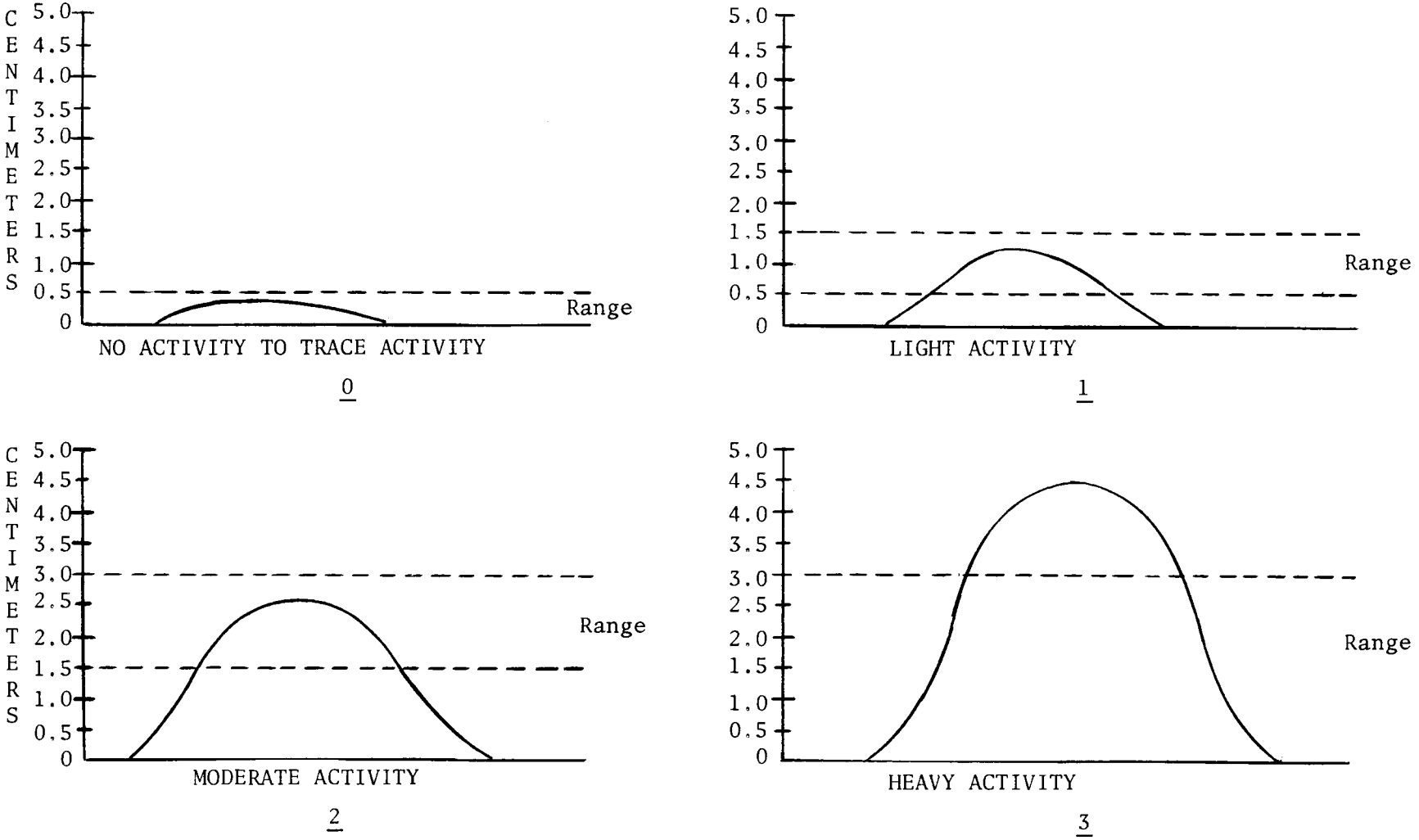
Each site was disinfected before the insertion of the electrode. After being disinfected, the needle was inserted to a depth approximately ranging from 3/8 of an inch to 3/4 of an inch depending solely

upon the total amount of subcutaneous tissue. The ground electrodes were placed approximately two inches below the acromion over the medial portion of the deltoid. The electrode connections were made by the means of brass springs described by Basmajian (5, p. 36). After connections were made, the placement of electrodes was tested by having the subject execute a lower arm flexion with resistance.

The electromyograph was calibrated to yield a one centimeter pen deflection per 200 micro volt input. The remote timer was used to indicate the start, the top, and the end of each movement involving lower arm flexion. In the case of adduction, the timer indicated the beginning and end of the movement. For flexion of the upper arm, the timer indicated the start, the top, and the end of these movements. Flexion of the upper arm from the extended position was marked from the start, to anatomical, to 90 degrees, to anatomical, and to the original starting position.

V. TREATMENT OF THE DATA

The investigator used a qualitative method of classification while analyzing muscle activity. A pen deflection from the baseline to .5 cm was considered as a trace of activity. A pen deflection from .5 to 1.5 cm was considered light activity. A pen deflection from 1.5 to 3.0 cm was considered moderate activity. Any pen deflection that was a value greater than 3.0 cm was considered heavy activity. This method is similar to one suggested by Basmajian (5, p. 47). This may be seen in Figure 1.



Grading Scale: 1 cm. = 200 mu

Figure 1. Grading scale for electrical activity.

CHAPTER IV

RESULTS AND CONCLUSIONS

The biceps brachii has been described as a muscle which is responsible for flexion of the arm and forearm, drawing of the humerus towards the glenoid fossa, and supinating the lower arm and hand. This investigation was utilized to differentiate the functions of the long head and short head in supinated and pronated positions. The functions of the biceps brachii have been analyzed in terms of the supinated position, but its function in pronated positions is still questionable as far as previous research is concerned.

The long head was most effective in movements that required flexion of the arm or forearm (Table I). For flexion of the lower arm supinated and without resistance, the long head was active in four subjects to a moderate or heavy degree (Figure 2). For flexion of the lower arm supinated and with resistance, the long head was active to a moderate or heavy degree in four out of five subjects (Figure 2). Flexion of the upper arm in a supinated position showed that four out of five subjects exhibited moderate to heavy activity (Figure 2). Flexion of the upper arm from the extended position in a supinated position showed that all subjects yielded activity ranging from moderate to heavy (Figure 2).

The short head was most active or effective in movements that required supinated flexion of the arm or forearm (Table II). For

TABLE I

FUNCTIONS OF THE LONG HEAD BY GRADING SCALE

Subject	Flexion of Lower Arm		Flexion of Lower Arm		Adduction of Arm	Flexion of Upper Arm	Flexion of Upper Arm	Flexion of Upper Arm Extended	Flexion of Upper Arm Extended
	A-UR	A-R	B-UR	B-R		A-R	B-R	A-R	B-R
E. C.	3	3	1	1	1	3	2	3	2
N. S.	2	2	0	2	1	2	2	2	1
G. L.	3	3	2	3	2	3	3	3	3
G. W.	3	3	1	2	1	3	1	3	2
J. L.	0	1	0	0	1	1	0	2	0

Key: A - Supinated
B - Pronated
UR - Unresisted
R - Resisted
0 - No to Trace Activity
1 - Light Activity
2 - Moderate Activity
3 - Heavy Activity

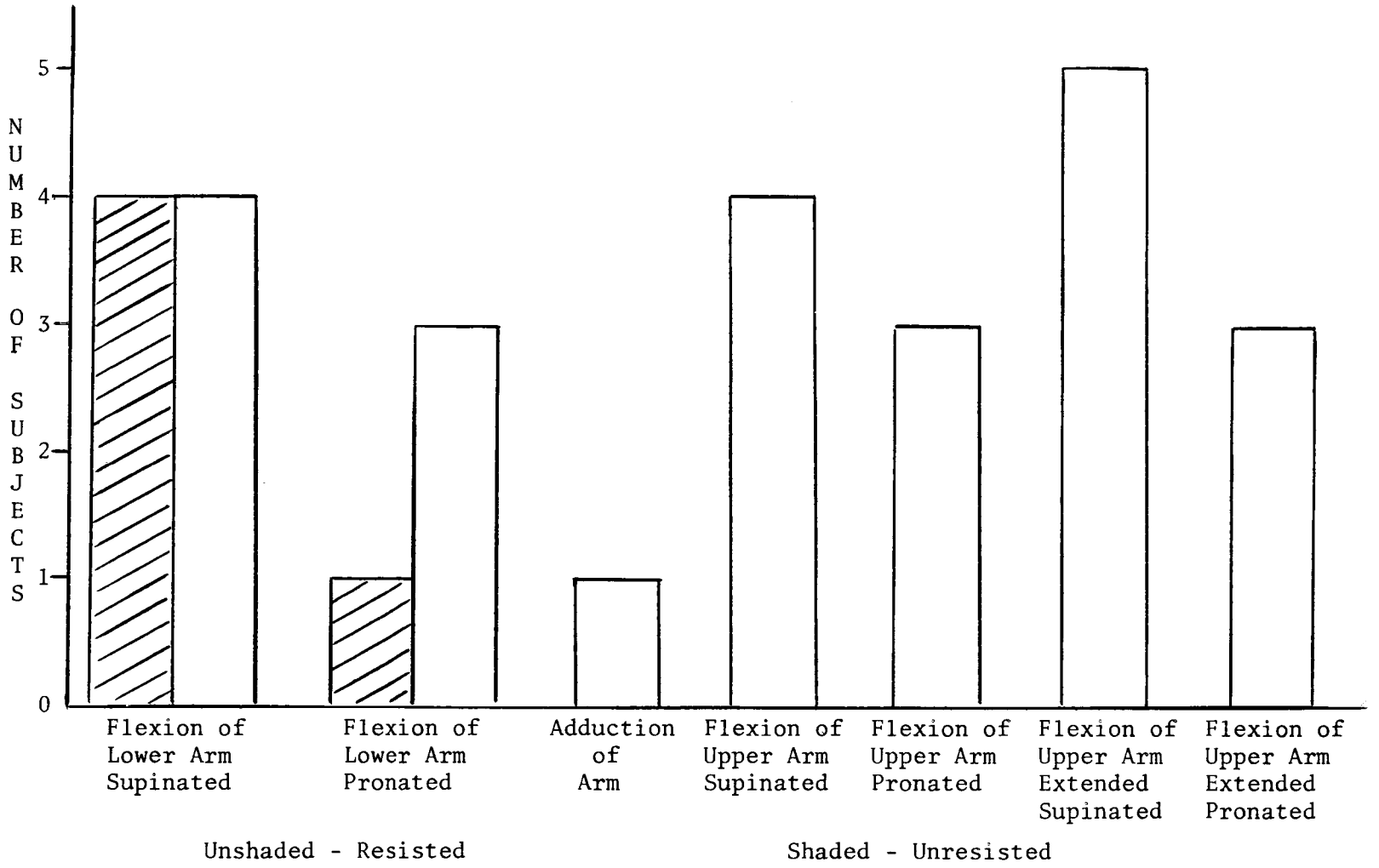


Figure 2. Subjects registering moderate or heavy activity in the long head.

TABLE II

FUNCTIONS OF THE SHORT HEAD BY GRADING SCALE

Subject	Flexion of Lower Arm		Flexion of Lower Arm		Adduction of Arm	Flexion of Upper Arm	Flexion of Upper Arm	Flexion of Upper Arm Extended	Flexion of Upper Arm Extended
	A-UR	A-R	B-UR	B-R		A-R	B-R	A-R	B-R
E. C.	1	3	1	3	3	3	3	3	3
N. S.	1	3	0	3	2	3	2	3	2
G. L.	1	3	2	2	3	3	3	3	3
G. W.	2	3	1	2	2	3	2	2	2
J. L.	3	3	3	2	3	3	1	3	1

Key: A - Supinated
B - Pronated
UR - Unresisted
R - Resisted
0 - No to Trace Activity
1 - Light Activity
2 - Moderate Activity
3 - Heavy Activity

flexion of the lower arm supinated and without resistance, the short head was active in two out of five subjects (Figure 3). For flexion of the lower arm supinated with resistance, the short head was active in five subjects will all exhibiting moderate to heavy activity (Figure 3). Flexion of the upper arm in a supinated position showed that five subjects registered activity that was moderate to heavy (Figure 3). For flexion of the upper arm from the extended in a supinated position, all five subjects registered from moderate to heavy (Figure 3).

The results of this investigation should be related to previously cited literature. Sullivan and others discovered that the most conspicuous increase in amplitude in the biceps occurred during movements while the forearm was supinated (22, p. 246). This is in agreement with Basmajian and Latif who stated that the biceps acts best when the forearm is supinated (8, p. 1106-1118). Rasch and Burke also agreed that recorded electromyographic potentials from the biceps were greater when the arm was in the supinated position (20, p. 228). This is in agreement with the investigator's findings.

Pansky and House stated that the long head is responsible for flexion of the supinated are and forearm (18, p. 198). This is in disagreement with the investigator's findings that the short head was the more active (Figure 2, p. 18). Basmajian contends that the long head is the more active of the two in flexion of the upper arm (5, p. 165). This also disagrees with the investigator's findings (Figure 2, p. 18). Sullivan and others reported that the maximum amplitude potential was

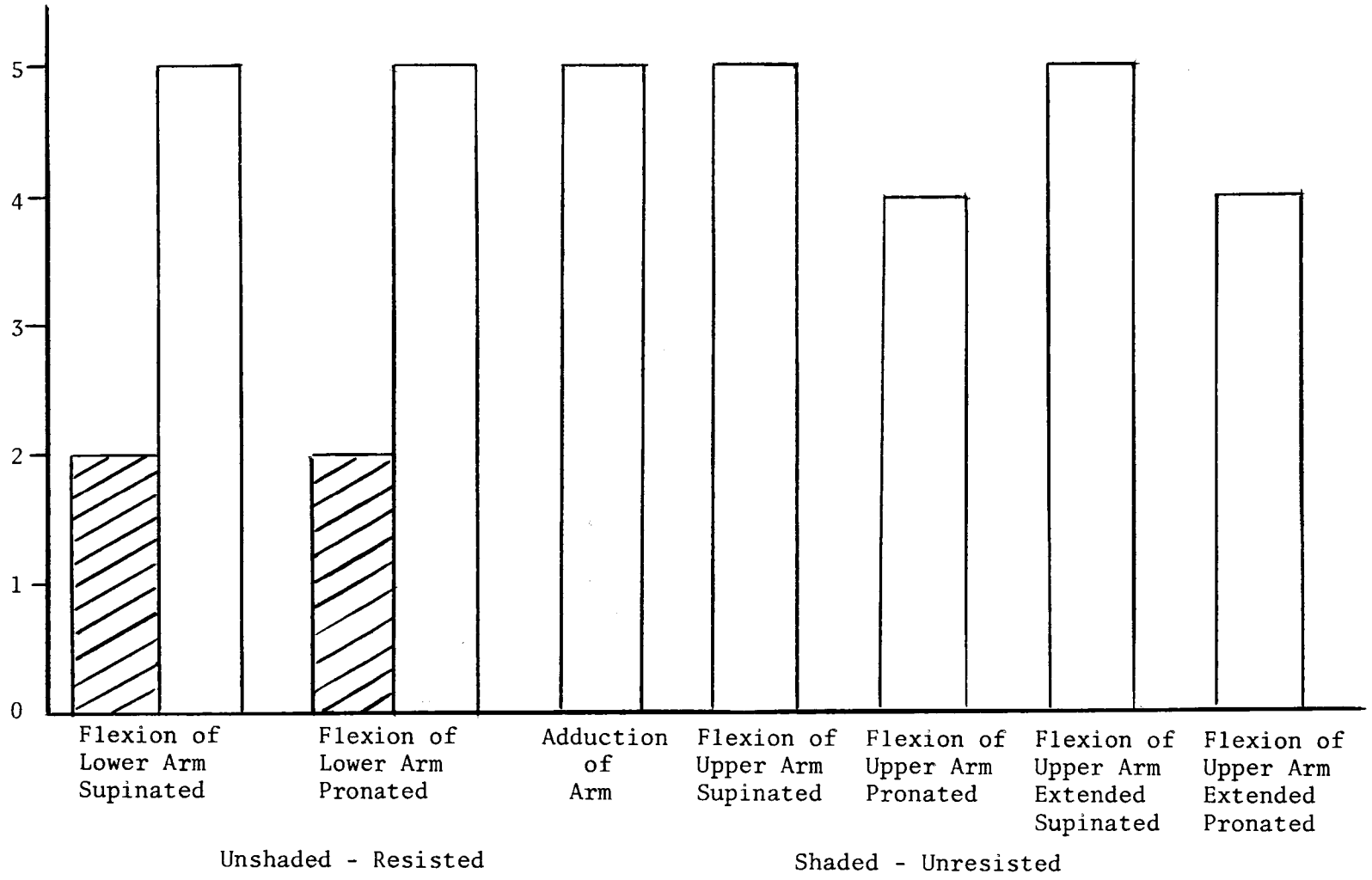


Figure 3. Subjects registering moderate or heavy activity in the short head.

recorded from the short head with the forearm supine and an added load of 2.0 kg (22, p. 248). This is in agreement with the investigator's reports (Figure 3, p. 21).

Adduction of the arm in only one of the subjects showed activity above the moderate range in the long head (Figure 2, p. 18). In the short head, all five of the subjects showed activity that was higher than moderate in the range scale (Figure 3). This is partially in agreement with Jacob and Francone who stated that the long head draws the humerus towards the glenoid fossa (16, p. 147). The investigator reported that both heads were active in adduction of the arm, but the short head was more active (Figure 3).

For flexion of the lower arm pronated and without resistance, only one subject registered activity that was above the moderate mark in the long head (Figure 2). For flexion of the lower arm pronated and with resistance, three subjects registered activity that was greater than the moderate mark (Figure 2). For flexion of the upper arm pronated, the long head registered moderate to heavy activity in three subjects (Figure 2). For flexion of the upper arm from the extended position in a pronated position, the long head registered activity that was moderate to heavy in three subjects (Figure 2).

For flexion of the lower arm pronated and without resistance, two subjects registered activity that was above the moderate mark (Figure 3). For flexion of the lower arm pronated and with resistance, all five subjects registered activity that was over the moderate mark in the short head (Figure 3). Flexion of the upper arm in the pronated

position did yield that four subjects had activity in the short head ranging from moderate to heavy (Figure 3, p. 21). Flexion of upper arm from the extended in a pronated position showed that four subjects yielded ratings above that of moderate (Figure 3).

Basmajian and Latif stated that the biceps acts least well during pronated movements (8, 1106-1118). This is in agreement with the findings of the investigator. This is also in agreement with Slaughter who stated that recorded action potentials are smaller at the end of the movement when the hand is pronated (21, 326-335). Sullivan and others also agreed with those previously cited that recordings were of a lower amplitude when forearm was pronated (22, p. 246). Travill and Basmajian contend that the biceps was never active during pronation (23, p. 559). This is in disagreement with the investigator's findings.

Some students contend that the long head contracts during a pronated movement while the short head fails to show any signs of activity (20, p. 228). This is in disagreement with the investigator's findings (Figure 3). Basmajian and Latif indicated that the long head showed signs of only slight activity in pronated movements (8, p. 1106-1118). This is in disagreement with the findings of the investigator who discovered more activity in the short head (Figure 3).

This discussion must include an exposition on the mechanical advantage of the short head of the biceps brachii. It originates from the coracoid process and inserts at the tuberosity of the radius. The long head originates at the supraglenoid tuberosity at the upper margin of the glenoid cavity and inserts at the tuberosity of the radius. It

can be safely expected that the short head will derive some form of a mechanical advantage over the long head because of its anatomical location and structure.

The findings of the investigator can be applied to a variety of theories and principles. They could be utilized as an explanation as to why people can generally execute a greater amount of pull-ups while in a supinated position. According to the findings of the investigator, the biceps is called into action during the supinated movements more than the pronated movements. This would contradict the previously conceived notion that prone pull-ups increase even greater the strength of the biceps brachii. According to the findings of the investigator illustrated in Tables I and II (pp. 17 and 19), this does not appear to hold true.

I. CONCLUSIONS

1. Both heads were effective during flexion of the supinated lower arm.
2. Flexion of the lower arm pronated showed both heads were active, but the short head appeared to be the more active.
3. In adduction, the short head was very active and the long head was slightly active.
4. Both heads were active during flexion of the upper arm while supinated; however, the short head was slightly more active.
5. Flexion of the upper arm while pronated showed that both heads were active with the short head being the more active.

6. Both heads were effective during flexion of the upper arm from the extended position while supinated.
7. Flexion of the upper arm pronated showed both heads were effective, but as in other pronated movements the short head was more active.

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