To the Graduate Council:

I am submitting herewith a thesis written by Melinda Jacque Voorhies entitled "A Fine-Wire Electromyographic Investigation of the Anterior, Middle and Posterior Portions of the Deltoid Muscle." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Physical Education.

E. Capen

Edward K. Capen
Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:

Hilton A. Smith

Vice Chancellor
Graduate Studies and Research

A FINE-WIRE ELECTROMYOGRAPHIC INVESTIGATION OF THE ANTERIOR, MIDDLE AND POSTERIOR PORTIONS OF THE DELTOID MUSCLE

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee

Melinda Jacque Voorhies

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To friends, the writer expresses special thanks for their support, encouragement and assistance through this year—it has made her year one to remember. To her parents: "It is an undoubted truth, that the less one has to do, the less time one finds to do it in. One yawns, one procrastinates, one can do it when one will, and therefore one seldom does it at all (Lord Chesterfield, Letters, 30, September, 1757)."

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ABSTRACT

The purpose of this study was to investigate the functions of the anterior, middle and posterior portions of the deltoid muscle through the use of fine-wire electromyography. The electrical activity of the anterior, middle and posterior deltoid was recorded during flexion of the humerus, flexion of the humerus from extension, abduction of the humerus, adduction of the humerus, extension of the humerus, extension of the humerus from flexion, medial rotation of the humerus, and lateral rotation of the humerus.

Integrated recordings from six subjects were obtained on a Model 7P3-D Grass Electromyograph calibrated to yield a one centimeter pen deflection per 200 micro volt input. These integrated recordings were qualitatively evaluated on the following scale: trace activity—pen deflection less than .5 centimeters, light activity—pen deflection above .5 centimeters but below 1.5 centimeters, moderate activity —pen deflection above 1.5 centimeters but below 3 centimeters, and heavy activity—pen deflection above 3 centimeters.

Results showed that the anterior deltoid was a flexor of the humerus in all subjects and was an abductor of the humerus in four of the subjects. The middle deltoid was an abductor of the humerus in all subjects and was a flexor of

the humerus in four of the subjects. The posterior deltoid was an extensor of the humerus and an abductor of the humerus in all subjects. No activity was exhibited in either medial rotation or lateral rotation of the humerus.

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CHAPTER I

INTRODUCTION

The foundation of electromyography is based on Galvani's findings that skeletal muscles will contract when stimulated electrically and will produce a detectable current (1, p. 1). Credit for growth of this new technique of collecting electrical potentials of muscles must be given to Adrian and Bronk, Denny and Brown, and others (1, p. 5). Marked improvement in the technology and availability of electronic apparatus, and continued interest and investigation of the actions and functions of muscles by such men as Basmajian, Pauly, Scheving, and others, have led to the increased use of electromyography for this knowledge.

Unlike most other methods, electromyography reveals the function of deep, impalpable muscles and the exact time sequences of activity (1, pp. 24-25). Fine-wire, bipolar, intramuscular electrodes are as broad in their pick-up as surface electrodes, but better for accurate indication of activity in single muscles (1, p. 35). By penetrating into the muscle and eliminating the activity of surrounding and underlying muscles, indwelling electrodes are more desirable for precision of muscle activity.

I. STATEMENT OF THE PROBLEM

The purpose of this study was to investigate, through the use of intramuscular electrodes, the function of the anterior, middle and posterior portions of the deltoid muscle during movements of the upper arm. Each part of the deltoid was investigated during the following movements: (1) flexion, (2) flexion from extension, (3) abduction, (4) adduction, (5) extension, (6) extension from flexion, (7) medial rotation, and (8) lateral rotation; with each subject seated upright with his arm straight and hanging in the relaxed neutral position (the forearm between pronation and supination) as his orientation point.

II. VALUE OF THE STUDY

Electromyographic investigations of the deltoid have been scarce and most have been through surface electromyography. Two of the better studies in their investigations of the deltoid muscle were Scheving and Pauly's (9, pp. 239-245), and Yamshon and Bierman's (10, pp. 286-289). The present study is part replication in the use of some of the basic movements of the humerus with flexion from extension and extension from flexion added, but various degrees of movement were omitted. Anatomy textbooks tend to agree in the description of the primary functions of the three

portions of the deltoid muscle. It was felt more research of the deltoid muscle was needed through the use of more precise and sensitive electromyographic techniques to substantiate the primary functions of the deltoid muscle as stated by basic anatomy textbooks.

This investigator attempted to establish the function each portion of the deltoid muscle played in each of the movements through the use of fine-wire, bipolar, intramuscular electrodes.

III. LIMITATIONS AND ASSUMPTIONS

Limitations and assumptions which applied to this study were as follows:

1. The techniques utilized by the subjects required no special training.

2. Age, sex, and physical condition of the subjects had no effect on a study of this kind.

3. The reliability and validity of the electromyographic recording equipment used could not be verified beyond the manufacturer's stated standards, except by careful calibration before and after each recording session.

4. The fine-wire electrodes were precise in the pick-up of the electrical activity of the portions of the muscle in which they were inserted.

5. Integrated recording data can be qualitatively evaluated as to the level of activity within a given muscle.

CHAPTER II

REVIEW OF RELATED LITERATURE

There were two major considerations in reviewing the available literature: (1) the descriptions of the functions of the three portions of the deltoid muscle as reviewed by Basmajian and (2) the functions of the deltoid muscle as revealed by the literature dealing with electromyographic investigations.

I. TEXTBOOK DESCRIPTION

Basmajian compiled the results of various authors on electromyographic investigations of the three portions of the deltoid muscle. It was felt this text's descriptions of the functions of the deltoid muscle were substantial for this study's background.

Scheving and Pauly, and Yamshon and Bierman (1, p. 196) found all three portions of the deltoid muscle were active in all movements of the arm. In flexion and medial rotation, the anterior was more active than the posterior; in extension and lateral rotation, the posterior was the most active; and in abduction, the middle portion was the most active.

These recommendations were not endorsed by Wertheimer and Ferraz and Shevlin (1, pp. 196-197). They found the

anterior portion of the deltoid's principal action was forward flexion and participated slightly in abduction. The middle portion was an abductor and acted slightly in flexion and extension. The posterior portion's principal action was in extension, slight and inconsistent in abduction, and minimal in lateral rotation. Their studies revealed the deltoid muscle does not participate in medial rotation.

II. ELECTROMYOGRAPHIC INVESTIGATIONS

A review of the literature concerning the research relative to electromyography indicated the studies were scarce and the majority of these studies used the less precise technique of electromyography, surface electromyography. Basmajian and Bazant (2, 1182-1186) used intramuscular electromyography but dealt with static loading and unloading with different weights, not movements of the upper arm. Inman, Saunders and Abbott (7, 1-30) found through the use of intramuscular electrodes in their study of the upper arm that the deltoid muscle registered action potentials in flexion and was an active abductor.

Yamshon and Bierman (10, pp. 286-289) in testing the three portions of the deltoid muscle, used no resistance and found all portions take part in flexion, abduction, and hyperextension. The anterior was an internal rotator and the posterior was an external rotator. Results were inconclusive

in adduction except that small potentials were observed in the anterior portion. McCloy in his study reported that in flexion of the upper arm, the anterior and middle portions of the deltoid muscle registered action potentials and in abduction, the same (8, p. 254).

Bearn used surface electromyography (6, pp. 103-107) and found that with no resistance, activity ceased in all portions of the deltoid muscle, but a minimal abducting movement showed a burst of activity in anterior and middle portions and only slightly in the posterior portion of the deltoid. Surface electromyography by Scheving and Pauly (9, pp. 239-245) showed the deltoid muscle was active in all movements of the arm. Flexion against no resistance showed pronounced anterior action and against resistance, the middle and posterior fibers became active. Extension and adduction showed all portions active with the posterior portion more active. Abduction showed all portions active with the middle more active. All three portions were active in medial rotation except when resistance was applied and the anterior portion stopped contracting. Lateral rotation showed activity from the middle and posterior fibers and only very slight activity from the anterior portion.

CHAPTER III

PROCEDURE

The purpose of this chapter is to describe the procedure used by this investigator in meeting the following steps of the study: (1) selection of the testing apparatus, (2) selection of the subjects, (3) the instructional program, (4) the tests, (5) administration of the tests, and (6) treatment of the data.

I. SELECTION OF THE TESTING APPARATUS

Approximately twenty-one weeks were utilized in 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 obtained.

Electromyographic Equipment

The basic instrument used in this study was a Model 7P3-D Grass Electromyograph, manufactured by Grass Instrument Company, Quincy, Massachusetts. This model consists of a four channel recorder having four wide-band direct-current preamplifiers, four integrator units, four alternating current amplifiers, and four ink-writing oscillographs. The oscillographs used were of the d'Arsenval galvonometertype,

with pen deflections proportional to current delivered by the driver amplifiers. The integrator produced a curved line representing the averaged amplitudes and frequencies of raw data input.

Electrodes

Bipolar electrodes were constructed and sterilized according to procedures described by Basmajian and Steko (4, p. 849). The wire used was Karma alloy wire .025 mm in diameter and manufactured by Wilbur B. Driver Corporation, Newark, New Jersey. Needles were of the disposable type, 27 gauge short.

Additional Equipment

An Exer-genie, calibrated at 5 lbs. resistance, was used to insure uniformity of movement and resistance in subjects. Subjects sat in a straightback chair to insure proper sitting posture. Fine-wire electrodes and their various parts were sterilized with a Fisher dry heat oven built by Fisher Scientific Company. All equipment was housed and operated in a copper lined Faraday room.

II. SELECTION OF THE SUBJECTS

The subjects were volunteers from the graduate physical education population at The University of Tennessee, Knoxville, Tennessee.

III. THE INSTRUCTIONAL PROGRAM

There was no special training required of the subjects other than learning to abduct, flex, extend, adduct, medially rotate, and laterally rotate the humerus.

IV. THE TESTS

Six basic anatomical movements, flexion, abduction, adduction, extension, medial rotation, and lateral rotation of the humerus, were performed. Each subject performed three executions of each movement unresisted and three executions of each movement resisted, with the exception of medial and lateral rotation which was performed three times resisted. The completion of these executions was considered as one trial.

V. ADMINISTRATION OF THE TESTS

The subjects were seated in an erect position slightly to the side of the chair with the right arm to the outside of the chair to prevent any contact with the chair during movement of the arm. In this position, the subject's arm was straight and hanging in the relaxed neutral position (the forearm between pronation and supination) as the orientation point. One fine-wire electrode was inserted into the anterior portion of the deltoid muscle approximately

two inches below the lateral end of the clavicle. In the middle fibers another electrode was inserted two inches below the lateral border of the acromion, and in the posterior portion an electrode was inserted about three inches below the spine of the scapula. The depth the electrode was inserted was determined by subcutaneous skin-fold measurements over the area in consideration.

With the electrodes in place and the electromyograph calibrated to yield one centimeter deflection per 200 micro volt input the subject began the series of movements. The first movement was flexion of the humerus to shoulder height and return to the neutral position. The subjects then flexed from extension, abducted to shoulder height, adducted, extended one-quarter of the way back, extended from flexion, medially rotated and laterally rotated the humerus. Each of the movements described was performed and the arm was returned to the relaxed neutral position for the next movement. With the exception of medial and lateral rotation which was performed three times resisted, each movement described was performed three times unresisted and three times resisted. The five pounds resistance was provided by the Exer-genie except in the case of medial and lateral rotation. Resistance in medial and lateral rotation was in the form of manual resistance of the elbow with the hands so that movement was more difficult.

VI. TREATMENT OF THE DATA

A qualitative evaluation of the integrated recordings was made. The grading of these recordings was based on the scale described below and illustrated in Figure 1, which is similar to that used by Basmajian (1, p. 47).

Grade

0 Trace activity—pen deflection of less than .5 centimeters.

X Light activity—pen deflection above .5 centimeters but below 1.5 centimeters.

XX Moderate activity—pen deflection above 1.5 centimeters but below 3 centimeters.

XXX Heavy activity—pen deflection above 3 centimeters.

Each graded value of a particular movement is the average of six executions of that movement.

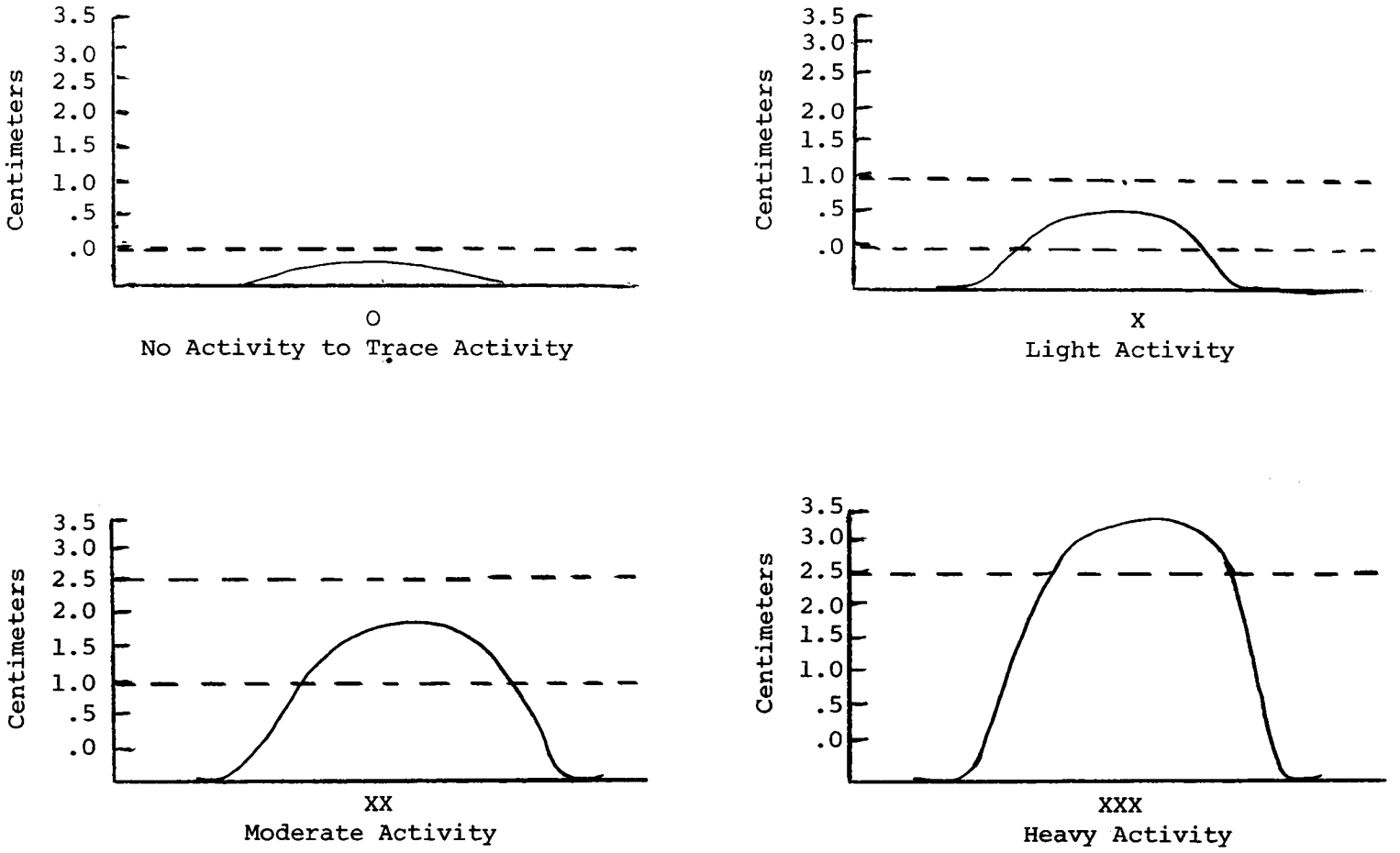

Figure 1. Grading scale.

CHAPTER IV

RESULTS

The data were analyzed by a rating scale as illustrated in Figure 1. The results of the investigation were divided into three parts: (1) the results of the anterior portion of the deltoid muscle during resisted and unresisted movements, (2) the results of the middle portion of the deltoid muscle during resisted and unresisted movements, and (3) the results of the posterior portion of the deltoid muscle during resisted and unresisted movements.

I. ANTERIOR DELTOID

The complete findings of the investigation of the anterior portion of the deltoid muscle are shown in Table I and a graphic representation can be seen in Figure 2.

The anterior portion of the deltoid muscle is most often described as a flexor of the humerus. The results of this investigation supported this description functionally as all subjects' anterior deltoid exhibited moderate or heavy activity during flexion. Flexion of the humerus from extension, unresisted, showed moderate or heavy activity in five of the six subjects and all subjects showed moderate or heavy activity when resisted.

TABLE I

FUNCTIONS OF ANTERIOR DELTOID MUSCLE BY GRADING SCALE[a]

Movements		Subjects					
		MV	DM	GL	SY	TD	WH
Flexion of the Humerus	(U[b])	XXX	XXX	XX	XX	XX	XXX
	(R[c])	XXX	XXX	XX	XXX	XX	XXX
Flexion of the Humerus from Extension	(U)	XXX	XXX	XX	XX	x	XXX
	(R)	XXX	XXX	XXX	XXX	XX	XXX
Abduction of the Humerus	(U)	X	XX	O	O	X	X
	(R)	XXX	XX	O	XX	X	XX
Adduction of the Humerus	(U)	O	X	O	X	O	O
	(R)	O	X	O	O	O	O
Extension of the Humerus	(U)	O	X	O	O	O	X
	(R)	O	XX	O	O	O	XX
Extension of the Humerus from Flexion	(U)	O	XX	X	X	X	XX
	(R)	O	XX	X	O	O	XX
Medial Rotation of the Humerus	(R)	O	XX	O	O	O	O
Lateral Rotation of the Humerus	(R)	O	XX	O	O	O	O

[a]O = trace activity; X = light activity; XX = moderate activity; XXX = heavy activity.

[b]Unresisted. [c]Resisted.

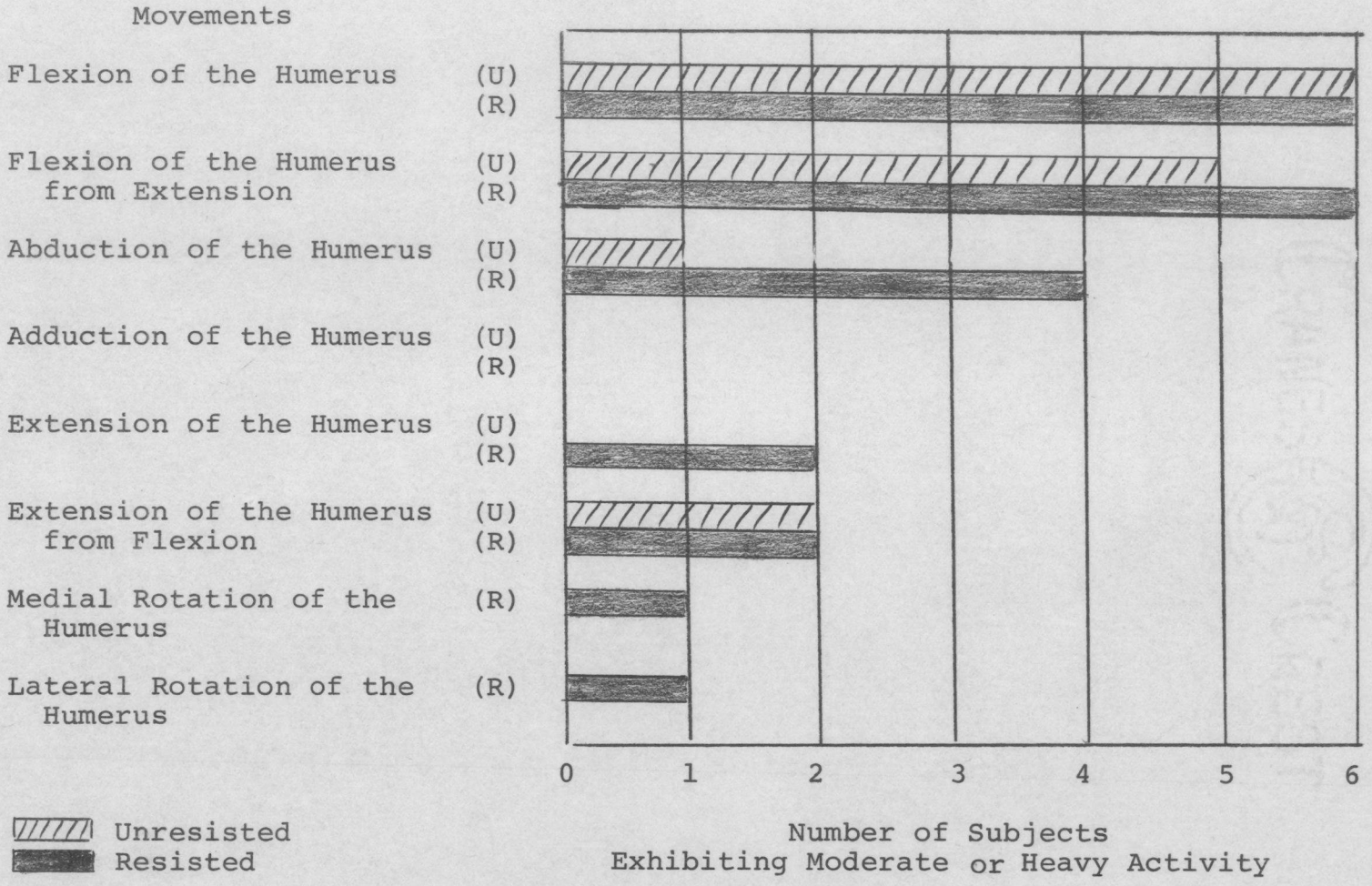

Figure 2. Frequency of activity—anterior deltoid.

Abduction of the humerus, unresisted, showed only one of six subjects with moderate or heavy activity, but when resisted four of the six subjects exhibited moderate or heavy activity. Adduction, resisted and unresisted, showed no moderate or heavy activity in any of the subjects.

Resisted extension of the humerus indicated moderate or heavy activity in two of six subjects. Extension from flexion, resisted and unresisted, showed two of six subjects with moderate or heavy activity.

Medial and lateral rotation of the humerus showed only one of six subjects with moderate or heavy activity.

II. MIDDLE DELTOID

The complete findings of the investigation of the middle portion of the deltoid muscle are shown in Table II and a graphic representation can be seen in Figure 3.

The middle portion of the deltoid is most often described as an abductor of the humerus. This investigation supported this description as all subjects' middle deltoid exhibited moderate or heavy activity in both resisted and unresisted movements. Adduction of the humerus showed two of six subjects with moderate or heavy activity unresisted.

Two of six subjects exhibited moderate or heavy activity during unresisted flexion of the humerus as compared to four of six when flexion of the humerus was resisted. Flexion of

TABLE II

FUNCTIONS OF MIDDLE DELTOID MUSCLE BY GRADING SCALE[a]

Movements		Subjects					
		MV	DM	GL	SY	TD	WH
Flexion of the Humerus	(U[b])	X	XXX	X	XX	O	O
	(R[c])	XX	XXX	XX	XXX	O	O
Flexion of the Humerus from Extension	(U)	X	XXX	X	XX	X	X
	(R)	XXX	XXX	X	XXX	XX	X
Abduction of the Humerus	(U)	XX	XXX	XXX	XX	XXX	XXX
	(R)	XXX	XXX	XXX	XXX	XXX	XXX
Adduction of the Humerus	(U)	O	XX	X	X	XX	O
	(R)	O	X	X	X	X	O
Extension of the Humerus	(U)	O	X	O	O	O	O
	(R)	X	XX	XXX	O	X	X
Extension of the Humerus from Flexion	(U)	O	XX	X	X	X	O
	(R)	O	XX	XX	O	O	O
Medial Rotation of the Humerus	(R)	O	XX	XX	O	O	X
Lateral Rotation of the Humerus	(R)	O	XX	X	O	O	O

[a]O = trace activity; X = light activity; XX = moderate activity; XXX = heavy activity.

[b]Unresisted. [c]Resisted.

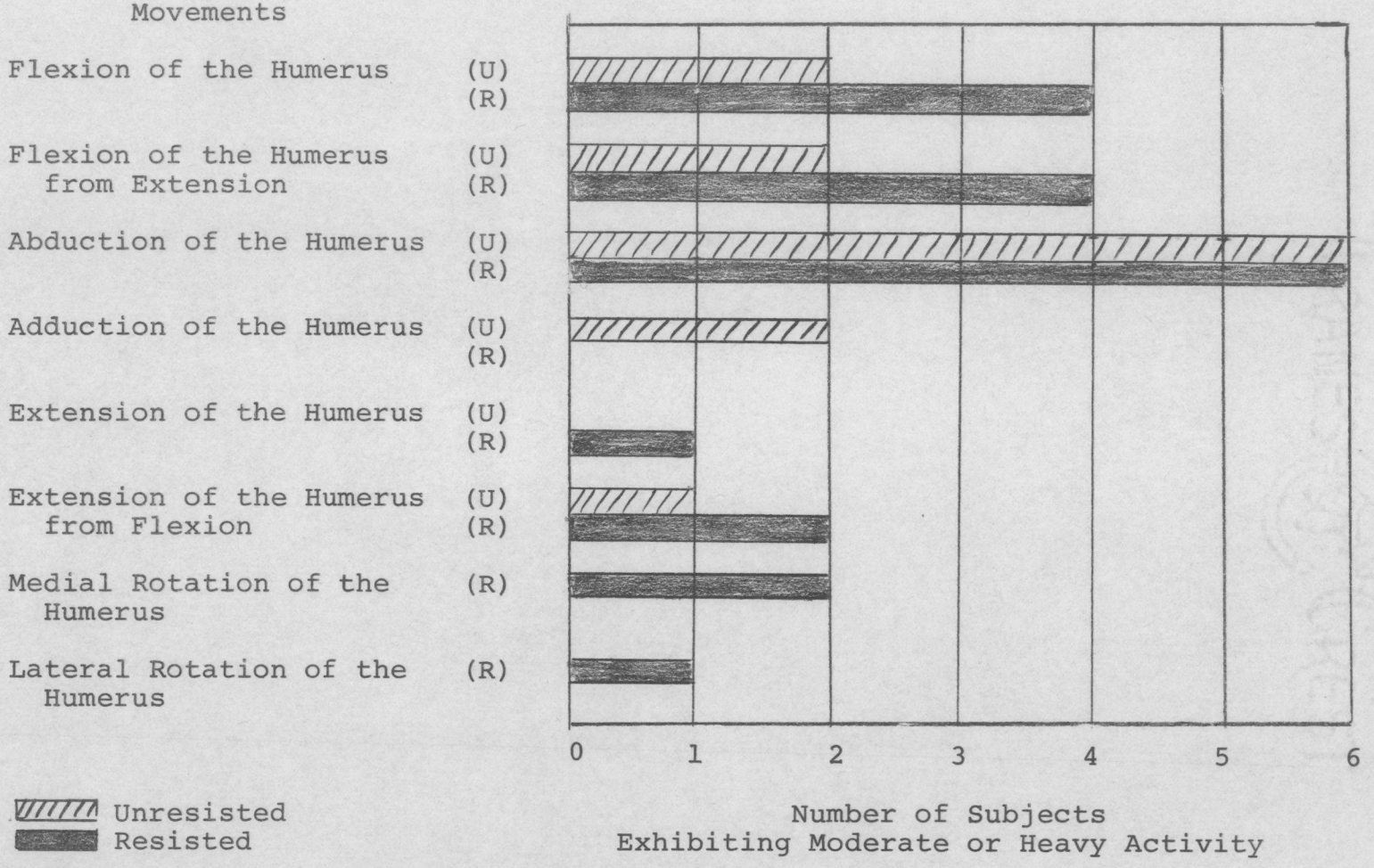

Figure 3. Frequency of activity—middle deltoid.

the humerus from extension elicited the same results as flexion in both resisted and unresisted movement.

During extension of the humerus, two of six subjects displayed moderate or heavy activity when resisted. One of six subjects displayed the same activity during extension of the humerus from flexion when unresisted. Two of six subjects showed moderate or heavy activity during the same movement resisted.

Only two subjects exhibited moderate or heavy activity during medial rotation, and lateral rotation showed only one subject with such activity.

III. POSTERIOR DELTOID

The complete findings of the investigation of the posterior portion of the deltoid muscle are shown in Table III and a graphic representation can be seen in Figure 4.

The posterior portion of the deltoid is most often described as an extensor of the humerus. This investigation supported this functional description as all subjects' posterior deltoid exhibited moderate or heavy activity in unresisted extension and five of six subjects showed this activity when extension was resisted. Extension of the humerus from flexion showed five of six subjects exhibiting moderate or heavy activity when both resisted and unresisted.

TABLE III

FUNCTIONS OF POSTERIOR DELTOID MUSCLE BY GRADING SCALE[a]

Movements		Subjects					
		MV	DM	GL	SY	TD	WH
Flexion of the Humerus	(U[b])	X	O	XX	X	O	O
	(R[c])	XXX	X	XX	XX	O	O
Flexion of the Humerus from Extension	(U)	O	X	XX	X	X	O
	(R)	O	X	XX	XX	X	O
Abduction of the Humerus	(U)	X	XX	XX	XXX	X	X
	(R)	XX	XXX	XXX	XXX	XX	XXX
Adduction of the Humerus	(U)	O	O	XX	XX	O	X
	(R)	O	O	X	X	O	O
Extension of the Humerus	(U)	XX	XX	XX	XX	XX	XXX
	(R)	XX	XXX	XXX	X	XXX	XXX
Extension of the Humerus from Flexion	(U)	XX	XX	XXX	X	XX	XX
	(R)	XXX	XXX	XXX	X	XXX	XX
Medial Rotation of the Humerus	(R)	X	O	X	X	O	O
Lateral Rotation of the Humerus	(R)	O	O	X	O	X	O

[a]O = trace activity; X = light activity; XX = moderate activity; XXX = heavy activity.

[b]Unresisted. [c]Resisted.

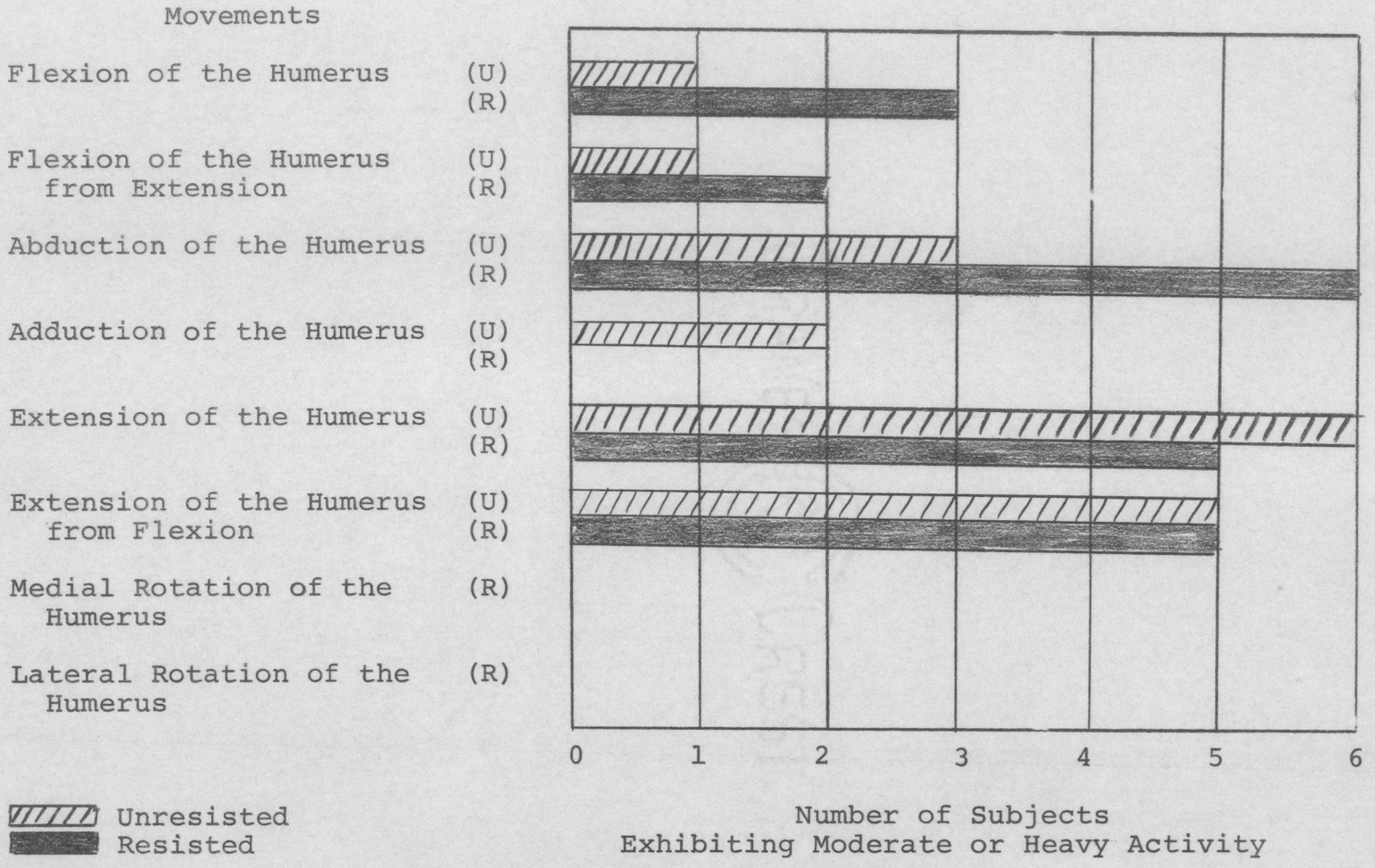

Figure 4. Frequency of activity—posterior deltoid.

During flexion of the humerus one of six subjects displayed moderate or heavy activity when unresisted as compared to two of six when flexion was resisted. Flexion of the humerus from extension showed the same results when resisted and unresisted as flexion.

Abduction of the humerus unresisted showed three of six subjects with moderate or heavy activity. Resisted abduction exhibited moderate or heavy activity in all six subjects. Adduction of the humerus showed two of the six subjects tested with the same activity when unresisted in movement.

None of the subjects tested exhibited moderate or heavy activity during medial and lateral rotation of the humerus.

CHAPTER V

DISCUSSION AND CONCLUSIONS

I. DISCUSSION

The Anterior Deltoid Muscle

The standard textbooks of anatomy and kinesiology describe the anterior portion of the deltoid as a flexor of the humerus. This investigation confirmed this description, but the investigation also indicated that when flexing the humerus from extension the anterior portion of the deltoid did not come into action until after the subject's arm had reached the neutral position and started the movement forward. However, recorded data indicated that the anterior portion was more active in the beginning phase of the movement from extension when resisted.

While no material was found that described the anterior deltoid as an abductor of the humerus, four of the six subjects tested exhibited moderate or heavy activity during humerus abduction.

The Middle Deltoid Muscle

The middle portion of the deltoid is most often described as an abductor of the humerus. This investigation verified this description.

Data also showed four of the six subjects tested with moderate or heavy activity in flexion of the humerus and flexion of the humerus from extension. The same findings were indicated in flexion of the humerus from extension as the anterior portion of the deltoid when resisted and unresisted.

The Posterior Deltoid Muscle

Extension of the humerus has been described as the major function of the posterior portion of the deltoid. This investigation supported this description, but the data also indicated that when extending the humerus from flexion, the posterior portion of the deltoid did not exhibit action potentials until after the subject had reached the neutral position and started the movement back to the extended position. Data showed the posterior portion, when resisted, more active in the beginning phase of the movement from flexion.

Research has not described the posterior deltoid as an abductor of the humerus, but in this investigation, all six of the subjects tested exhibited moderate or heavy activity in abduction of the humerus.

II. CONCLUSIONS

The findings of this investigation appear to warrant the following conclusions:

1. The anterior deltoid is a flexor of the humerus in all subjects and is an abductor of the humerus in some subjects.
2. The middle deltoid is an abductor of the humerus in all subjects and is a flexor of the humerus in some subjects.
3. The posterior deltoid is an extensor of the humerus in all subjects and is an abductor of the humerus in all subjects when resisted and some subjects when unresisted.

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VITA

Melinda Jacque Voorhies was born in Bunkie, Louisiana, on February 6, 1951. She attended elementary and high school in Avoyelles Parish and graduated from Bunkie High School in May, 1969. In September of that year she entered Northwestern State University in Natchitoches, Louisiana, and was graduated in May, 1973, with a major in Health, Safety and Physical Education. She entered The University of Tennessee, Knoxville, in September, 1973, and taught as a graduate assistant through the Knox County School System at Vestal Elementary School. Her Master of Science Degree in Physical Education was conferred in August, 1974. She will be a physical education instructor and women's basketball coach at the University of Montevallo, Montevallo, Alabama, beginning August, 1974.