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A Comparison of the Effects of Two Therapeutic Exercises on the Muscle Action Potential of the Vastus Medialis

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A COMPARISON OF THE EFFECTS OF TWO THERAPEUTIC EXERCISES

ON THE MUSCLE ACTION POTENTIAL OF THE VASTUS MEDIALIS

(TITLE)

BY

Janet J. Lozar

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF

Master of Science

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

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A COMPARISON OF THE EFFECTS OF TWO THERAPEUTIC EXERCISES ON THE MUSCLE ACTION POTENTIAL OF THE VASTUS MEDIALIS

BY

JANET J. LOZAR

Bachelor of Science

Lock Haven State College

ABSTRACT OF THESIS

Submitted in partial fulfillment

of the requirements for the degree of

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in Physical Education at the Graduate School of

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ABSTRACT

Electromyography was utilized to compare the effects of two therapeutic exercises at two work loads in knee extension on the muscle action potential in the vastus medialis. One exercise was extension to 180 degrees with a four second isometric hold and flexion to 90 degrees. The other exercise was extension to 180 degrees, 15 degrees flexion, 15 degrees extension and flexion to 90 degrees. Each exercise lasted for 10 seconds.

The subjects in the study were 11 varsity female athletes from the fall and winter interscholastic athletic program at Eastern Illinois University. The subjects met for the first time to determine their work loads and to practice each exercise. The work loads were determined to be one-half and three-fourths of the maximum weight lifted to full knee extension. At a second meeting, data was collected from each subject for each exercise performed during two trials at two different work loads.

The research design consisted of a single-group with two variables. The amplitude of the spikes was measured and the frequencies of the spikes on each interference pattern were counted. A quantitative figure was obtained by multiplying mean amplitude by frequency for each trial. This score was utilized with a multiple analysis of variance program by the Eastern Illinois University Data Processing Cen-

ter.

A null hypothesis was tested at the .05 level of significance. The null hypothesis stated: Exercising the quadriceps femoris through a full range of motion plus repetition of the last 15 degrees does not increase the muscle action potential of the vastus medialis when compared to a full extension and flexion exercise with the same time duration.

Major findings of the study concluded that there was no difference in the muscle action potential in the two exercises. There was a significant difference in the muscle action potential due to the increase in weights between one-half maximum weight and three-fourths maximum weight.

ACKNOWLEDGEMENTS

The writer sincerely appreciates the aid given by Dr. William Buckellew and Dr. Russell Fischer in the organization of this study. Their generous professional contributions were greatly appreciated.

Gratitude is also extended to Mr. Dennis Aten, Head Athletic Trainer, Eastern Illinois University, and Dr. Thomas Woodall for their availability in guidance and interest in this research project.

The cooperation and interest of the subjects was greatly admired and appreciated.

Appreciation is extended to my father, Frank Lozar, who constructed the Slant Frame for use in Exercise B.

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INTRODUCTION

There are many views taken by authorities concerning therapeutic exercise for the quadriceps femoris muscle group. There are numerous studies which attempt to seek an efficient strength building program for the quadricep femoris. Factors which influence different rehabilitation programs consist of the type of equipment used, the number of sets or repetitions incorporated into a program, different ranges of motion to be worked, and the body position for the exercise.

Types of equipment available for therapeutic exercise vary from cans filled with cement to more sophisticated machinery available from manufacturers. Manufactured strength building equipment include free weights, pulley systems, extensor tables and isokinetic machines. Each type of equipment is a factor in the performance of therapeutic exercise.

The number of sets and repetitions within a set may influence muscular activity during performance of therapeutic exercise. Variations of different strength building programs could include many sets with few repetitions, many sets with many repetitions, few sets with many repetitions and few sets with few repetitions.

Muscular activity may be influenced if performance incorporates an entire range of motion or parts of the range of motion. The influence of range of motion may be a factor in muscular activity which could effect the strength gain of a muscle.

Different body positions could alter the muscular activity of a muscle. One particular body position may not isolate the muscle under study which would effect the muscular activity.

In addition to various rehabilatation programs for the quadriceps femoris muscle group, different beliefs concerning selective function of each quadricep muscle is also under constant evaluation. In particular, there is a conflict between researchers concerning the function of the vastus medialis. There is a discrepancy concerning where the most activity of the vastus medialis occurs in the range of motion of knee extension. The main discrepancy of the function of the vastus medialis is concerned with the most activity produced in the last 15 degrees of knee extension or whether the vastus medialis exerts the same amount of activity throughout the range of motion of knee extension.

There are some researchers who believe that the individual quadriceps femoris muscles have a selective function. The belief that an individual quadricep femoris muscle has a specific task in movement or protection from injuries to the knee sets excellent ground work in studying that muscle.[1] This study serves to examine the vastus medialis in comparing the effect of two therapeutic exercises on the muscle action potential.

PURPOSE OF THE STUDY

The purpose of this study was to compare the effects of two therapeutic exercises at two different work loads in knee extension on the muscle action potential in the vastus medialis.

NULL HYPOTHESIS

Exercising the quadriceps femoris through a full range of motion plus repetition of the last 15 degrees does not increase the muscle action potential of the vastus medi-

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[1]Ronald R. Bos, Thomas G. Blosser, "An Electromyographic Study of Vastus Medialis and Vastus Lateralis During Selected Isometric Exercises," Medicine and Science in Sports, II (Winter, 1970), p. 218; see also T.L. DeLorme, "Restoration of Muscle Power by Heavy Resistance Exercises," Journal of Bone and Joint Surgery, XXVII (1945), pp. 646, 648; see also F.J. Lieb, J. Perry, "Quadriceps Function, An Anatomical and Mechanical Study Using Amputated Limbs," Journal of Bone and Joint Surgery, L (Dec., 1968), pp. 1535, 1544, 1547; see also F.J. Lieb, J. Perry, "Quadriceps Function: An Electromyographic Study Under Isometric Conditions," Journal of Bone and Joint Surgery, LIII (June, 1971), pp. 749 757; see also G.S. Pocock, "Electromyographic Study of the Quadriceps During Resistive Exercises," Journal of the American Physical Therapy Association, XLIII (1963), pp. 427, 433; see also Seppo Santavirta, M.D., "Integrated Electromyography of the Vastus Medialis Muscle After Meniscectomy," The American Journal of Sports Medicine, VII (Jan./Feb., 1979), pp. 41, 42; see also M. Wheatley, W. Jahnke, "Electromyographic Study of the Superficial Thigh and Hip Muscles in Normal Individuals," Archives of Physical Medicine, (Aug., 1951), p. 513.

alis when compared to a full extension and flexion exercise with the same time duration.

ALTERNATE HYPOTHESES

There is no difference in the muscle action potential of performance in knee extension of one-half maximum weight that the athlete can lift and performance of three-fourths maximum weight that the athlete can lift.

A five minute interval between performances of the two exercises tested including varying weights of one-half maximum weight lifted and three-fourths maximum weight lifted will not have a fatigue effect on the muscle action potential of the vastus medialis.

IMPORTANCE OF THE STUDY

Importance of this study lies in efficiency of therapeutic exercise for muscle action potential of the vastus medialis. If one exercise will produce more muscle action potential of the vastus medialis over another exercise, then that exercise would be more efficient for the therapeutic aspects of the exercises.

LIMITATIONS - ASSUMPTIONS

A limitation in this study was the method used in establishing the maximum weight that the subjects would lift at the first meeting. This was done by trial and error and to a minimal degree in all cases, fatigue could have been a detriment.

Two surface electrodes of electromyography were used and placed over the motor point of the vastus medialis. Inter-electrode distance was .5 centimeter. The amount of interference from other subcutaneous tissues which lie over the vastus medialis was not known.[2]

The interference pattern of electromyography is a series of spikes as shown in Figure 1. Each spike was measured and counted. Since some spikes involved measurements of less than a millimeter, error in these finite measurements may have been an influence on some of the results.

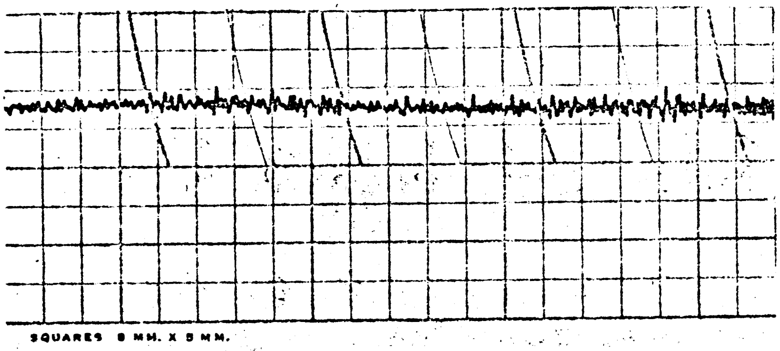

Figure 1

Interference Pattern of Electromyography

Another limitation concerning this study involved the decision as to which leg was dominant. The dominant leg was the same leg that the subjects would use to kick a ball. This was the leg used for testing purposes.

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[2]Santavirta, op. cit., p. 41.

The environment of the testing area was a limiting factor. Although the testing area was screened off with a white curtain, noise of other people in the room was unavoidable.

A limitation to this study was the lack of repeated measures which should accompany an electromyographical study. This is a factor which could have a direct influence of the results and conclusions of the study.

There are numerous factors involved with the electrical activity of muscular contractions. An assumption is that electromyography is indirectly related to muscular force.[3] Previous studies have demonstrated that a stronger individual shows less electrical activity for a muscular contraction.[4]

TERMINOLOGY

The following are definitions for terms used in this study.

Concentric Contraction

A concentric contraction is an unresisted shortening of a muscle.[5]

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[3] Ibid.

[4] Herbert A. DeVries, Physiology of Exercise for Physical Education and Athletics, 2nd ed. (Dubuque, Iowa: Wm. C. Brown Co., Publishers, 1976), p. 293.

[5] Laurence E. Morehouse, Ph.D., August T. Miller, Jr., M.D., Ph.D., Physiology of Exercise, 6th ed. (St. Louis: The C.V. Mosby Co, 1971), p. 78.

Dominant Leg

The dominant leg corresponded to the dominant arm. The dominant leg was established by ascertaining which leg the subject would use to kick a ball. If the subject would kick a ball with her right leg, then that leg was used as the dominant leg in the study.

Eccentric Contraction

An eccentric contraction occurs when a muscle expends enough energy to produce force that is less than the opposing outside force.[6] Even though the muscle tries to shorten, it is lengthened during its contraction phase.[7]

Electromyography

Electromyography measures muscle action potential during contraction of the muscle.[8] Electromyography was the measuring tool used in this study. EMG is an abbreviation for electromyography.

Exercise A

This exercise consisted of knee extension from 90 degrees to 180 degrees with a four second hold at 180 degrees and followed by flexion to 90 degrees. The exercise lasted for 10 seconds and each command denoted one second. The command for this exercise was: "up - two - three - hold

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[6]DeVries, op. cit., p. 45. [7]Ibid.

[8]Ibid., p. 286.

- two - three - four - down - two - three."

Exercise A, One-half Max

This was Exercise A performed at one-half the maximum weight that the subject could lift which was established at a previous meeting before the testing day.

Exercise A, Three-fourths Max

This was Exercise A performed at three-fourths of the maximum weight that the subject could lift which was established previously.

Exercise B

Exercise B was an exercise in knee extension which consisted of extension from 90 degrees to 180 degrees, 15 degrees flexion, 15 degrees extension, and flexion to 90 degrees. This exercise lasted 10 seconds with each command denoting one second. The commands for Exercise B were: "up - two - three - down - two - up - two - down - two - three."

Exercise B, One-half Max

Exercise B, one-half max was Exercise B performed at one-half the maximum weight that the subject established prior to the testing day.

Exercise B, Three-fourths Max

This exercise was Exercise B performed at three-fourths maximum weight that the subject could lift. This was established before the testing day.

Interference Pattern

Electromyographical recordings of muscular contractions are interference patterns. This measurement, or interference pattern, when analyzed gives information concerning the electrical activity of the muscle.[9] An example of an interference pattern is shown in Figure 1, page 5.

Isokinetics

Isokinetics are a form of muscular training which employ resistance throughout the range of motion at a constant speed. Isokinetics allow explosive, high-speed muscular activity to increase strength.[10]

Isometric Contraction

An isometric contraction is a contraction in which the muscle does not shorten. No movement is produced and no work is performed.[11]

Isotonic Contraction

An isotonic contraction shortens the muscle against

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[9]Ibid., p. 288.

[10]Rick Hall, Athletic Trainer, opinions expressed in an address, ("Which to Use and When to Use Isotonic, Isometric or Isokinetic Exercises") at the Great Lakes Athletic Trainers Association Convention, Distric 4, Holiday Inn, Perrysburg, Ohio, March 16, 1979.

[11]Morehouse, Miller, op. cit., p. 309.

a load which allows movement and the performance of work.[12]

Muscle Action Potential

A muscle action potential is the electrical activity occurring in muscle tissue during contraction.[13] MAP is an abbreviation for muscle action potential.

Max Weight

Max weight is the maximum amount of weight that the subjects could lift on knee extension to 180 degrees for one performance. This was established by trial and error at the first meeting.

Motor Point

The motor point is that part of the muscle where impulses are conducted.[14] This was found to be in the belly of the muscle. Synonyms for motor point are motor end plate and neuromuscular junction.

Motor Unit

A motor unit is composed of the neuron and its axon and the muscle fibers supplied by the branches of the axon.[15]

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[12]Ibid. [13]DeVries, op. cit., p. 286.

[14]Esther M. Greisheimer, Physiology and Anatomy With Practical Considerations, (Philadelphia, Pennsylvania: J.B. Lippincott Company, 1963), p. 211.

[15]DeVries, op. cit., p. 15.

Physiograph

A physiograph was a machine used to record the muscle action potential of the vastus medialis.

Slant Frame

A slant frame as shown in Figures 2 and 3 was a piece of apparatus used in this study so that the subjects would be able to identify 15 degrees of flexion and extension during performance of Exercise B. This apparatus consisted of two wooden frames braced together so that the top of the apparatus was slanted at 15 degrees. After the first extension phase, the researcher strung the ropes across the frame so that during the first flexion phase the subject's back of leg would touch the rope. When the subject felt the rope on the back of her leg, she knew she had flexed 15 degrees. During the second extension phase the researcher dropped the ropes so that the second flexion phase of 90 degrees would be reached.

Volt-Ohm-Milliammeter

A volt-ohm-milliammeter was a small battery operated piece of equipment which was used to measure the skin resistance for skin preparation.

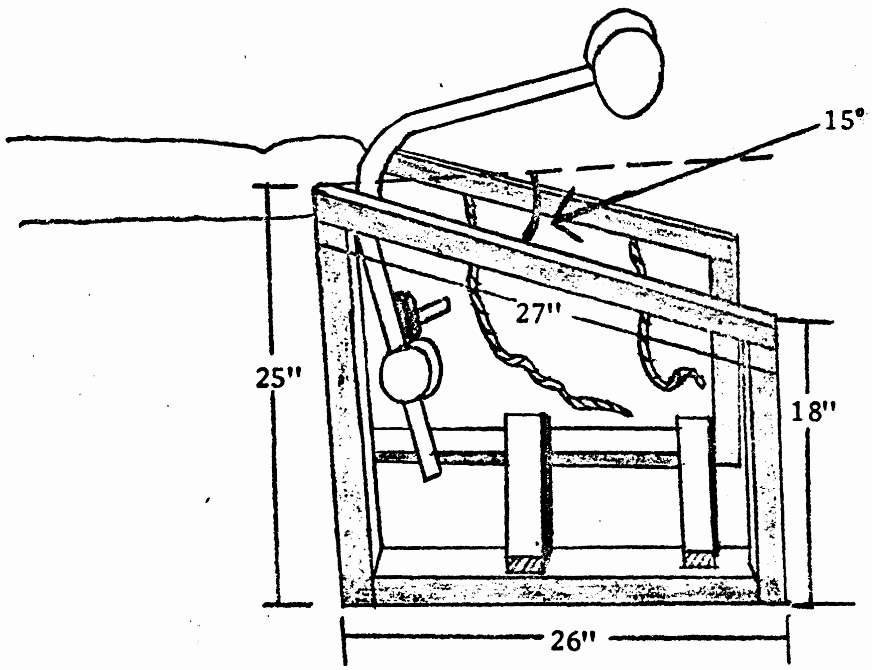

Figure 2

Slant Frame - Lateral View

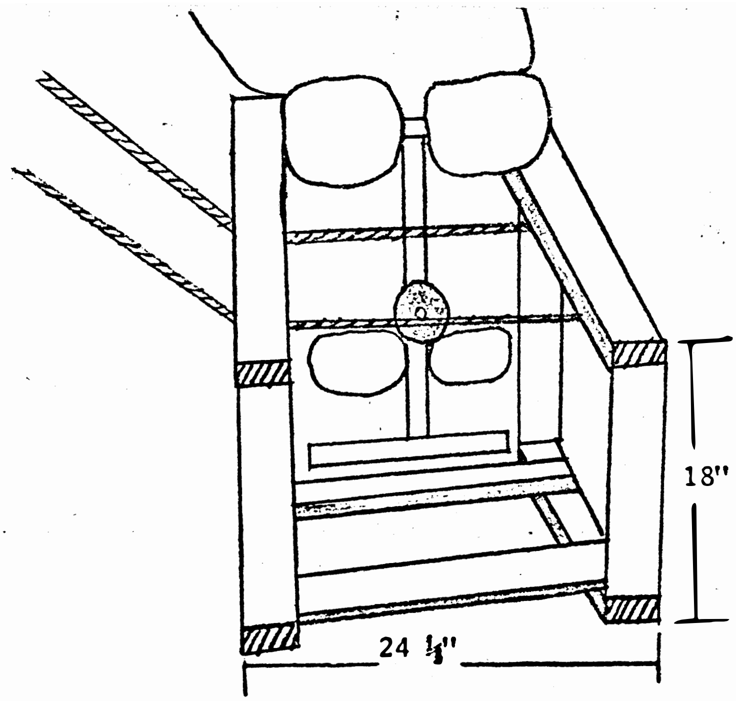

Figure 3

Slant Frame - Anterior View

Chapter 2

REVIEW OF RELATED LITERATURE

The literature was reviewed to provide related information pertaining to the study. Included in the review was the value of therapeutic exercise; isolating the vastus medialis; aspects of therapeutic exercise which included information on equipment and repetitions of exercise; eccentric and concentric contractions; isokinetic, isometric and isotonic exercises; stabilization; and electromyography which presented information on the history of electromyography, electromyographical techniques, and interpretation techniques.

VALUE OF THERAPEUTIC EXERCISE

Therapeutic exercise for the quadriceps femoris muscle group, in general, has been advocated for the prevention and rehabilitation of knee injuries. Common knee injuries in athletics are ligamentous in nature. According to DeLorme, strength in the supporting muscles which cross the knee joint gives stability to the knee.[1] The quadriceps femoris

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[1]T.L. DeLorme, "Restoration of Muscle Power by Heavy Resistance Exercises," Journal of Bone and Joint Surgery, XXVII (1945), p. 657.

play an important role in fighting trauma to the knee. Consequently, Perrin explains, if the quadriceps femoris are weak, the knee must rely solely on the other muscles that cross the knee joint and the cruciate and collateral ligaments.[2] Under these conditions of partial strength, the foundation of the knee is weakened and it is vulnerable to trauma which could inflict structural damage. Therefore, strength development in the quadriceps femoris is indicated to prevent knee injuries and to rehabilitate fully the injured knee.

Abbott and Kress conducted a study with West Point Cadets to study the prevention of knee injuries with pre-season and in-season strength programs.[3] Cadets who had previous histories of knee injuries were administered an isometric strength program of exercises which concentrated on their lower extremities. The exercise program consisted of a warm-up session of bench stepping, followed by isometric knee extensions against a wall at 105 and 150 degrees, toe rising, knee flexion and extension by use of a pulley system and hip and knee extensions.[4] In addition to the strength program, the cadets were allowed to participate in intercollegiate and

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[2]David H. Perrin, M.A., "A Comparison of Two Methods of Developing Quadriceps Muscle Strength," Orthopaedic/Sports Medicine, III (Winter, 1978), p. 4.

[3]G. Abbott, B. Kress, "Preconditioning in the Prevention of Knee Injuries," Archives of Physical Medicine and Rehabilitation, L (June, 1969), p. 326.

[4]Ibid., p. 328.

intramural athletics. Concluded from the study was that the lack of major knee injuries suggested the value of the strength program in the prevention of further knee injuries.

ISOLATING THE VASTUS MEDIALIS

Research has paved the way for much controversy concerning the selective function of each individual quadriceps femoris muscle. The vastus medialis and its function is the predominant instigator of the controversy. There are beliefs that the vastus medialis functions mainly in the last 15 degrees of knee extension.[5] Because of this selective function some researchers feel that strength to the vastus medialis is essential for maximum knee joint stability. Therefore these researchers would base their therapeutic exercise program to concentrate on the final extensor force to strengthen the vastus medialis.

Some studies have shown that there is no selective function of the vastus medialis. It would be the feeling here that the quadriceps femoris muscle group functions as a unit throughout the range of motion in knee extension.[6]

In 1945, DeLorme organized a strength program using knee extension in which he emphasized complete extension with

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[5] M. Wheatley, W. Jahnke, "Electromyographic Study of the Superficial Thigh and Hip Muscles in Normal Individuals," Archives of Physical Medicine, (August, 1951), p. 513.

[6] G.S. Pocock, "Electromyographic Study of the Quadriceps During Resistive Exercises," Journal of the American Physical Therapy Association, XLIII (1963), p. 433.

each repetition because he felt that the vastus medialis functions chiefly in the last 15 degrees of extension.[7]

Through the use of electromyography, in 1951, Wheatley and Jahnke studied the superficial thigh and hip muscles and found that the rectus femoris initiated leg extension and the vastus medialis and vastus lateralis showed the greatest activity in the last stages of the range of motion.[8] The electromyography in this study showed that the vastus medialis also exerted greater activity when the knee was held in extension than did the other components of the quadriceps femoris.[9] This study of leg extension through the use of electromyography was done on individuals who had not had knee injuries or were not involved in a strength training program.

It wasn't until 1963 when another major study was completed that the disagreement concerning the function of the vastus medialis evolved. Pocock studied the quadriceps femoris using electromyography and found that there was no distinctive timing of the individual activities of each head of the quadriceps femoris on knee extension.[10] The muscles which were measured according to their electrical activity with electromyography were the rectus femoris, vastus medialis and vastus lateralis. The following exercises were

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[7]DeLorme, op. cit., p. 646.

[8]Wheatley, Jahnke, loc. cit. [9]Ibid.

[10]Pocock, loc. cit.

studied:

1. Active knee extension with no weight load.

2. Knee extension with a Noland-Kuckhoff Table, the exercise bar was arranged for decreasing and increasing resistance as the knee extended.

3. Knee extension with a Storm's quadriceps exercise board which has pulley lifts.

4. Knee extension with an adapted pulley system.

5. Knee extension with a conventional pulley system.

6. Knee extension with a DeLorme quadricep exercise boot.

7. Maximum isometric quadricep contraction with the knee in full extension studied in the sitting and supine positions.[11]

Pocock disputed through lack of convincing evidence that the vastus medialis contracts strongly only in the last 15 degrees of extension. Electromyography registered similar action potential patterns throughout the entire range of motion for the rectus femoris, vastus medialis and vastus lateralis.

In 1968, Lieb and Perry studied amputated limbs anatomically and mechanically in knee extension to determine whether the vastus medialis provides the final extensor force. By using 22 cadaver specimens, they were able to identify the direction of pull from each quadriceps muscle. Each cadaver had not had knee surgery or a knee problem during life.

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[11]Pocock, op. cit., p. 428.

Through a pulley system and a weight attached to each head of the quadriceps muscles, they were then able to determine an effective force from the desired degree of extension. Their conclusions suggested that the only selective function attributable to the vastus medialis was patellar alignment.[12] Through an anatomical analysis, they inferred that the early visual atrophy of the vastus medialis following injury was attributed to a generally quadriceps femoris weakness. The differences between the vastus medialis and the other components of the quadriceps femoris are the thinness of the fascial covering of the vastus medialis and the extreme obliquity of its fibers.[13] These two factors accentuate the definition of the vastus medialis during contraction. Although all the quadriceps femoris muscles atrophy following injury, the lack of prominence of the vastus medialis is noticed first due to its composition.

In 1971, Lieb and Perry did another electromyographic study of quadriceps function under isometric conditions. Using frequency as the measure of muscle effort and disregarding amplitude on the interference pattern, they found that the only difference in the activity of the vastus medialis was that its action potential count was consistently two

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[12]F.J. Lieb, J. Perry, "Quadriceps Function, An Anatomical and Mechanical Study Using Amputated Limbs," Journal of Bone and Joint Surgery, L (December, 1968), p. 1547.

[13]Ibid., p. 1546.

times greater than the other quadricep muscles.[14] They felt that they could not attribute selective function to the vastus medialis. Again, Lieb and Perry referred to the misconception concerning selective function of the vastus medialis in the final 15 degrees of extension. In this study, they explained that due to knee injuries, the quick visual atrophy of the vastus medialis occurs along with the subjects inability to reach full extension. Therefore, because of the occurrence of these two factors together, it is often associated that the vastus medialis muscle alone is responsible for the final extension phase of the knee.[15]

In direct contrast to Lieb and Perry, Klein blames the quick atrophy of the vastus medialis post-injury on walking with the knee in partial flexion.[16] Klein believes that walking in partial flexion causes improper function of the vastus medialis. He calls the vastus medialis the "key to support of the knee" and should be seriously concentrated on during rehabilitation of the knee.[17]

Bos and Blosser undertook an electromyographic study of the vastus medialis and vastus lateralis during perform-

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[14]F.J. Lieb, J. Perry, "Quadriceps Function: An Electromyographic Study Under Isometric Conditions," Journal of Bone and Joint Surgery, LIII (June, 1971), p. 757.

[15]Ibid., p. 749.

[16]K.K. Klein, The Knee in Sports, (Austin, Texas: Pemberton Press, 1971), p. 5.

[17]Ibid., p. 5.

ance of three isometric exercises (1970).[18] Data was collected on 16 adult males. These individuals were physically active and ranged in ages from 19 to 38 years.

Each individual was administered six cable-tension tests to provide some basic data and a frame of reference for the electromyographic evaluation before they were tested on the three isometric exercises.

The following is a description of the three isometric exercises which were tested by Bos and Blosser: Exercise one consisted of a standing position with feet shoulder width apart, parallel and pointing straight ahead. The subject then forcibly extended both knees, pulling up on the patella with a maximal contraction of the quadriceps femoris. Exercise two required the subject to stand with the right lower extremity laterally rotated so that the right foot formed a 60 degree angle with the left foot. The right heel was placed two inches to the right of the ball of the left foot. The right foot was held in dorsal flexion so that the body weight was on the heel of the foot. The subject then forcibly extended the right leg at the knee joint, pulling up on the patella with a maximal contraction of the quadriceps femoris. For exercise three, the subject was in a standing position with the right lower extremity abducted

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[18] Ronald R. Bos, Thomas G. Blosser, "An Electromyographic Study of the Vastus Medialis and Vastus Lateralis During Selected Isometric Exercises," Medicine and Science in Sports, II (Winter, 1970), p. 218.

so that the right foot was just off the floor. The subject stood on the left foot with the aid of a support in front of the subject to maintain balance. The subject then forcibly extended the right leg at the knee joint by pulling up on the patella with a maximal contraction of the quadriceps muscles.

The purpose of studying the three isometric exercises was to compare and determine which exercise would be more beneficial for the prevention of knee injuries and the rehabilitation following injury and surgery. The exercises displayed varying action potentials of the vastus medialis and vastus lateralis. They suggested the vastus medialis and vastus lateralis aid in medial and lateral stability of the knee.[19]

A study by Jackson and Merrifield (1972) used five males and five females from the students and faculty at Ithaca College.[20] Selection of subjects was not discussed other than the fact that none had had a knee injury. Mean ages of the subjects were 24.4 years for females and 29.8 years for males. Muscle action potentials were recorded for progressive resistance exercise with a weighted boot at 90 degrees, during the range of motion of knee extension, and at 180 degrees extension.

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[19] Ibid.

[20] R.T. Jackson, H.H. Merrifield, "Electromyographic Assessment of Quadriceps Muscle Group During Knee Extension With Weighted Boot," Medicine and Science in Sports, IV (Summer, 1972), p. 116.

Results from Jackson and Merrifield's study showed an increase in the muscle action potential as more weight was added.[21] Also, the vastus medialis and vastus lateralis showed the greatest muscle action potential in the last stages of knee extension.[22] They inferred that the reason for the greater muscle action potential in the last stages of knee extension was due to the larger resistance torque at 180 degrees because of the length of the load's gravitational moment arm.[23] They did not agree with Wheatley and Jahnke that the vastus medialis has a selective function.[24]

Santavirta (1979) undertook an electromyographical study on subjects who had medial meniscectomies following tears of the medial meniscus.[25] The subjects were six males ranging in age from 22 to 56 years. Integrated electromyography recorded the muscle action potentials of the vastus medialis on knee extensions. The recordings began following five seconds of extension for a seven second measurement. The integrated electromyographical data was collected once preoperatively and at one week, one month, two months, and three months post-surgery. All data was compared to the other, non-surgical leg which served as the control.

Santavirta attributed the vastus medialis to be pri-

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[21]Ibid. [22]Ibid., p. 118. [23]Ibid.

[24]Wheatley, Jahnke, loc. cit.

[25]Seppo Santavirta, M.D., "Integrated Electromyography of the Vastus Medialis Muscle After Meniscectomy," The American Journal of Sports Medicine, VII (Jan./Feb., 1979), p. 40.

marily a stabilizer of the patella.[26] He noted that although the early atrophy of the vastus medialis was an indication of general quadriceps femoris weakness, the restoration of the vastus medialis was one of the main problems following medial meniscectomy even though the rest of the quadriceps femoris had practically reached values of the control leg.[27] He also noticed early fatigue in the vastus medialis on the operated leg when compared to the control leg three months post-surgery.[28]

ASPECTS OF THERAPEUTIC EXERCISE

In order to assign a therapeutic exercise program which will rehabilitate fully all the components of the quadriceps femoris, the investigation of the action of the vastus medialis must continue. There must be additional studies that will either support or negate a selective functioning of the vastus medialis.

There are numerous rehabilitation programs available which try to increase strength to the quadriceps femoris. Some of these programs attempt to concentrate on overloading the vastus medialis if there is a belief of selective functioning of the vastus medialis. Different types of contractions, methods of stabilization, repetitions and sets and various equipment or lack of equipment have all been studied.

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[26]Ibid., p. 42. [27]Ibid., p. 40.

[28]Ibid.

Equipment and Repetitions

According to Klein, DeLorme can be considered the first researcher to study exercise programs of the quadriceps femoris scientifically.[29] DeLorme's progressive resistive exercises with 10 repetitions by using a weighted boot has led to many similar programs with modifications that are in use today.[30] He advocated the function of the vastus medialis in the last 15 degrees of knee extension. If full extension could not be reached during the regular quadricep program, then only "terminal extension exercises" were performed.[31] Terminal extension exercises consisted of repeated exercise in which the only range of motion was in the last 15 to 20 degrees until the vastus medialis had built up sufficient strength to continue in the regular heavy-resistance and low-repetition exercises.

Pocock studied knee extension using various types of equipment ranging from different pulley systems, exercise boots and isometric contractions to determine the influence of different tension forces on the muscle action potential.[32] He observed that at varying tensions, the interference pattern was not affected other than the coorelated in-

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[29]Klein, op. cit., The Knee in Sports, p. 75.

[30]DeLorme, op. cit., "Restoration of Muscle Power by Heavy Resistance Exercises," p. 648.

[31]Klein, op. cit., p. 91.

[32]Pocock, op. cit., "Electromyographic Study of the Quadriceps During Resistive Exercises," p. 427.

crease or decrease of the overall amplitude of the interference pattern.[33]

Lack of knee injuries following a strength program of bench stepping, isometrics and isotonic exercises to West Point Cadets would indicate the value of strength programs for the lower extremity but did not advocate one type or phase of movement over another.[34]

Jackson and Merrifield utilized the weighted boot for an electromyographic assessment of the quadriceps femoris muscle group during knee extension. They tested five males and five females at 90 degrees, movement throughout the range of motion of knee extension and at 180 degrees to determine the muscle action potential of the rectus femoris, vastus medialis and vastus lateralis. They inferred that the weighted boot was detrimental to the ligamentous structure of the knee when the knee was flexed to 90 degrees.[35]

With a support under the weighted boot at 90 degrees flexion, Perrin found no difference between extensions with a weighted boot and a Universal Gym knee extension table.[36] Both types of equipment produced similar muscular activity

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[33]Ibid., p. 434.

[34]Abbott, Kress, loc. cit., "Preconditioning in the Prevention of Knee Injuries."

[35]Jackson, Merrifield, op. cit., "Electromyographic Assessment of Quadriceps Muscle Group During Knee Extension With Weighted Boot," p. 116.

[36]Perrin, op. cit., "A Comparison of Two Methods of Developing Quadriceps Muscle Strength," p. 6.

in the quadriceps femoris.

Eccentric and Concentric Contractions

Some rehabilitation programs employ various movements of the toes, foot, ankle and hip in order to strengthen the quadriceps femoris.[37] Basmajian studied the effect of these movements through electromyography on 11 women and found the results to be unreliable.[38] Movements of the toes, foot, ankle and hips did not augment the activity of the quadriceps femoris. Basmajian found that the most motor unit activity was when the subject actively performed extension of the knee against resistance during motion.[39] During this study, he noticed that concentric actions caused more electrical activity than eccentric contractions.[40]

Ostrom, in his experience with knee rehabilitation has noticed that eccentric training programs were more effective in producing force than concentric training programs.[41] This observation required scientific study which was lacking by Ostrom.

In an address on rehabilitation, Hall advocated the use of an eccentric strength contraction if the muscle was

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[37]J.V. Basmajian, M.D., Muscles Alive, Their Functions Revealed by Electromyography, 2nd ed. (Baltimore: The Williams and Wilking Co., 1967), p. 220.

[38]Ibid. [39]Ibid., p. 21. [40]Ibid.

[41]R.C. Ostrom, "Knee Rehabilitation Following Surgical Procedures," Physical Therapy, LVII (December, 1977), p. 1376.

too weak to perform concentric contractions.[42] This was a statement made on rehabilitation in general and the aim was to rehabilitate an injured body part as soon as possible following the injury regardless of the amount of strength already possessed by the injured part.

Isokinetic, Isometric and Isotonic Exercise

Following a serious injury or surgery to the knee, the athlete is not able to actively extend the lower leg. Many times extension of the knee is detrimental to the injury during the rehabilitation process so straight leg exercises are performed. Some of the more common straight leg exercises are quadriceps setting and straight leg raises.

Quadriceps setting can be performed immediately following injury or surgery to the knee. Quadriceps setting consists of an isometric contraction of the quadriceps femoris while the athlete is sitting in a straight leg position. The goal in quadriceps setting is to flatten the popliteal space against the floor during the contractions. Abbington, Baxter, Koepke, and Christopher found quadriceps setting to be uniformly best in the vastus medialis in their electromyographic evaluation as compared with the other

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[42]Rick Hall, Athletic Trainer, opinions expressed in an address, ("Which to Use and When to Use Isotonic, Isometric or Isokinetic Exercises") at the Great Lakes Athletic Trainers Association Convention, Distric 4, Holiday Inn, Perrysburg, Ohio, March 16, 1979.

quadriceps femoris muscles.[43] Quadriceps setting is an isometric exercise.

Straight leg raises are isotonic exercises in which the straight leg is lifted during hip flexion. The leg itself may be enough weight for the athlete to lift against gravity or manual resistance may be applied at various places on the leg. Abbington, Baxter, Koepke and Christopher noticed more electrical activity occurring in the quadriceps femoris during manual resistance with straight leg raises than during performance of quadriceps setting or straight leg raises without manual resistance.[44]

Three straight leg isometric exercises in various positions were studied by Bos and Blosser with an emphasis on the muscle action potential of the vastus medialis and vastus lateralis.[45] Although the three activities produced varying action potentials in the vastus medialis, there was no significant evidence which would advocate one exercise over another.[46] A general conclusion concerning the use of isometric exercise was that it was a practical way to increase the strength of the vastus medialis and vastus later-

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[43] R.O. Abbington, M.L. Baxter, G.H. Koepke, R.P. Christopher, "Strengthening Techniques of the Quadriceps Muscles: An Electromyographic Evaluation," Journal of the American Physical Therapy Association, XLVI (1966), p. 1175.

[44] Ibid., p. 1176.

[45] Bos, Blosser, op.cit., "An Electromyographic Study Of Vastus Medialis and Vastus Lateralis During Selected Isometric Exercises," p. 219.

[46] Ibid., p. 222.

alis since no equipment is needed. They recommended the use of maximal isometric contraction of the quadriceps femoris against resistance which would probably result in greater activity and therefore, development of the vastus medialis and vastus lateralis.[47]

Another opinion of rehabilitation is to make use of isokinetic, isometric and isotonic contractions since the benefits of each can be found in the performance of sport.[48] Perhaps the benefit of each form of contraction worked in the rehabilitation phase will contribute some time in the performance of sport. Where one form of exercise contraction is advantageous, it may lack a principle of rehabilitation that another type of exercise can give. For example, application of an isotonic rehabilitation program will not lend the benefits of the explosive speed that advocators of isokinetics demand.[49]

Stabilization

A strength program is of no value unless the muscle group to be worked is isolated and thereby worked to its optimum. In order to isolate the quadriceps femoris for knee extension, the back should be stabilized since greater muscular force can be produced when maximum stabilization is provided.[50]

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[47]Ibid. [48]Hall, loc. cit. [49]Ibid.

[50]H.M. Mendler, "Effect of Stabilization on Maximum Isometric Knee Extension Force," Physical Therapy, XLVII (1967), p. 377.

Currier tested 50 normal subjects, 20 men and 30 women, to determine the effect of back stabilization on isometric knee extension exercises.[51] The subjects were measured at 100, 110, 120, and 130 degrees of hip extension with a tensiometer to determine the knee extensor force.[52] He suggested that back stabilization between 110 and 130 degrees of hip extension provided the optimal workout.[53]

ELECTROMYOGRAPHY

Electromyography is a technique for recording of muscle action potentials by use of a high gain amplifier with a pen-writing recorder.[54]

A muscle action potential is recorded by electromyography when a motor unit is activated. An electrical disturbance passes from the anterior horn cell, down the axon to the neuromuscular junction where a liberation of chemicals initiate a wave of excitation along each muscle fiber which command the muscle fiber to contract.[55] The muscle fiber action potentials represent the motor unit action potentials which become the electrical activity displayed by the

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[51]D.P. Currier, "Positioning for Knee Strengthening Exercises," Physical Therapy, LVII (February, 1977), p. 148.

[52]Ibid. [53]Ibid., p 151.

[54]Basmajian, op. cit., Muscles Alive, Their Functions Revealed by Electromyography, pp. 37, 44.

[55]Frank Krusen, M.D., Frederic J. Kottke, M.D., Paul M. Ellwood, Jr., M.D., Handbook for Physical Medicine and Rehabilitation, (Philadelphia: W.B. Saunders Co, 1965), p. 193.

electromyograph when an electrode is monitoring those particular motor units.[56]

History of Electromyography

Electromyography would not exist today if man had not questioned the function of muscles. This can be traced as far back as Aristotle and up to the eighteenth century when Galvani discovered that muscles produce electricity.[57] However, it wasn't until the twentieth century that scientists improved the recording and detecting of minute electrical discharges from muscles.[58] At this time electromyography was used mainly for diagnostic and clinical applications. After World War II electromyography became more functional for use by anatomists and kinesiologists.[59] From that time on, electromyography has been involved in numerous research studies to investigate muscular function.

Electromyographical Techniques

Apparatus required for electromyography includes an electromyograph and electrodes. Electromyographs are varied in their sophistication of recording muscle action potentials with an array of possible accessories. All electromyographs consist of an amplifier, control unit, and power supply unit.[60] Some electromyographs also possess oscilloscopes, linograph cameras and photographic film, FM recorder for sig-

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[56]Ibid. [57]Basmajian, op. cit., pp. 4, 5.

[58]Ibid., p. 5. [59]Ibid., p. 6. [60]Ibid., p. 38.

nals and inkwriting recorders.[61]

Muscle action potentials are transmitted from the motor unit to the electromyograph by electrodes. There are basically three types of electrodes in usage. These are surface electrodes, needle electrodes and fine-wire electrodes.[62]

Surface electrodes are placed on the skin over the muscle which is to be monitored. Adhesive washers on the electrodes enable them to remain in place. The electrical resistance must be lowered to practical levels to insure the electrical insulation between the muscle and electrode. It is suggested that 3,000 ohms is adequate for most research studies.[63] The removal of the dead surface layer of skin along with its protective oils reduces resistance.[64] This is accomplished by abrading the skin with fine sandpaper. Surface electrodes are convenient to use, however, they can be used only with superficial muscles and the monitoring area is non-discrete.[65]

The second type of electrode is the needle electrode. The needle electrode which is a hollow needle with a wire is inserted into the muscle and remains in place until

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[61] Basmajian, loc. cit.; see also Krusen, op. cit., p. 197.

[62] Krusen, op. cit., p. 195.

[63] Basmajian, op. cit., p. 24. [64] Ibid.

[65] Ibid., p. 25.

the data is collected.[66] Disadvantages in research studies for the needle electrode is that it responds only to a small representation of the total muscle because of its local area of monitoring.[67] Krusen also points out that there is some reduction on the amplitude of the muscle action potential with the needle electrode.[68] Needle electrodes must be sterilized before usage and they are somewhat painful since they must remain injected into the muscle during the collection of data.[69]

The third type of electrode is the fine-wire electrode. The fine-wire electrode consists of a fine-wire which is inserted into the muscle by a needle.[70] The needle is removed which allows the electrodes to remain in place in the muscle until the testing is completed. The only pain involved in the usage of fine-wire electrodes is the puncture from the needle at the initial insertion of the electrode.[71] The advantages of using fine-wire electrodes include the ease of implanting and withdrawing the electrodes, they give an accurate indication of activity in single muscles and they are broad in their pick-up from a specific muscle.[72]

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[66]Basmajian, op. cit., p. 26; see also Krusen, op. cit., p. 195.

[67]Basmajian, op. cit., p. 27.

[68]Krusen, loc. cit. [69]Basmajian, loc. cit.

[70]Ibid., p. 34. [71]Ibid.

[72]Ibid., p. 32.

Interpretation Techniques

Electromyography when recorded by a pen-writing apparatus produces an interference pattern. The recorded muscle action potentials are then examined so that conclusions can be made concerning the activity of the muscle which was studied. There are numerous methods which researchers employ in examining an interference pattern in order to arrive at an arbitrary quantitative figure for establishment of results.[73]

Basmajian suggests a method of counting spikes on the interference pattern.[74] This method was employed by Lieb and Perry (1971) in an electromyographic study of quadriceps function.[75] They felt they could measure muscle effort by counting the number of muscle action potentials/unit of time in order to quantify their results.

Another method described by Basmajian is a summation of the spikes, height and type of spike produced on the interference pattern.[76] Following this procedure, a classification system is employed to evaluate the results of the in-

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[73]Abbington, Baxter, Koepke, Christopher, op. cit., "Strengthening Techniques of the Quadriceps Muscles: An Electromyographic Evaluation," p. 1173; see also Basmajian, op. cit., pp. 46, 47; see also Jackson, Merrifield, op. cit., "Electromyographic Assessment of Quadriceps Muscle Group During Knee Extension With Weighted Boot," p. 117; see also Lieb, Perry, op. cit., "Quadriceps Function: An Electromyographic Study Under Isometric Conditions," p. 753.

[74]Basmajian, op. cit., p. 46.

[75]Lieb, Perry, loc. cit.

[76]Basmajian, op. cit., p. 47.

terference pattern. Bos and Blosser utilized a form of this method in their electromyographic study of isometric exercises on the vastus medialis and vastus lateralis.[77] They devised a seven point numerical scale to evaluate the amplitudes produced on the interference pattern.[78]

Measuring amplitudes and counting frequencies is another method of interpreting the data produced by electromyography. This method was used by Abbington, Baxter, Koepke, and Christopher in an electromyographic evaluation of strengthening techniques of the quadriceps muscles.[79] They established a quantitative figure following measurement of spikes and frequencies by multiplying amplitude times frequency in their evaluation.[80]

Jackson and Merrifield completed an electromyographic evaluation of knee extension with a weighted boot by utilizing the muscle action potential intensity values and averaging the peak deflections.[81] Their values were expressed in microvoltage.[82]

Basmajian discussed use of vector analysis for di-

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[77]Bos, Blosser, op. cit., "An Electromyographic Study of Vastus Medialis and Vastus Lateralis During Selected Isometric Exercises," p. 220.

[78]Ibid.

[79]Abbington, Baxter, Koepke, Christopher, loc. cit.

[80]Ibid. [81]Jackson, Merrifield, loc. cit.

[82]Ibid.

rect examination of interference patterns.[83] Vectors are applied to the muscle action potentials in order to establish a quantitative figure.[84]

Electromyography can also be quantified by use of an integrator.[85] An integrator is an electronic device which uses the variables of amplitude, frequency and spike shape to produce a quantitative figure for evaluation.[86] An integrator gives an immediate numerical read-out and does not require examination of an interference pattern. Santavirta utilized integrated electromyography in his evaluation of the vastus medialis following meniscectomy.[87]

SUMMARY

The review of related literature encouraged therapeutic exercise for the quadriceps femoris in order to give stability to the knee. The controversy concerning a possible selective function of the vastus medialis in knee extension presented conflicts in determining the appropriate therapeutic exercise program for the development of strength to each quadricep muscle. Factors which entered into therapeutic exercise programs included the selection of appropriate equipment; the number of sets and repetitions to be

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[83]Basmajian, op. cit., p. 48. [84]Ibid.

[85]Ibid., p. 47. [86]Ibid.

[87]Santavirta, loc. cit., "Integrated Electromyography of the Vastus Medialis Muscle After Meniscectomy."

worked; the type of muscular contraction desired such as eccentric or concentric contractions; whether to use isokinetic, isometric or isotonic exercises; and isolating the muscle group to be worked by stabilizing the appropriate body part.

Electromyography can be used to evaluate the effect an exercise has on the activity of a muscle. Electromyography will record the muscle action potential of a muscle during contraction. The interpretation of the interference pattern produced during muscular activity was an aid in evaluating the exercise and its effect on the muscle.

Chapter 3

METHODOLOGY

The subjects, methods, tests, instruments, collection of data, statistical procedure for analyzing data and design of the study to compare the effect that two therapeutic exercises have on the muscle action potential of the vastus medialis have been presented in this chapter.

SUBJECTS

The subjects who participated in this study were female athletes from the fall and winter intercollegiate varsity athletic teams at Eastern Illinois University, Charleston, Illinois.

All female athletes from the field hockey, volleyball, cross country, tennis, basketball, swimming, and badminton teams were screened by viewing their pre-season and previous physical examinations given by the Eastern Illinois University Health Service to determine whether they had had an injury within the past year which had disabled them from a practice or game. Regardless of the extent of recovery from an injury, these athletes were not acceptable. Also, any athlete who had a history of knee injuries was not eligible for participation in the study.

Following the initial screening process, 57 athletes were found eligible for the study. Letters were sent to 25 of these eligible female athletes who were selected at random from the group of 57. The letters requested their participation in the study. The athletes who responded to the letters numbered 11. These athletes became the subjects for the study.

Of the 11 subjects, two were field hockey players, three were volleyball players, two athletes played tennis of which one of these was also a badminton player, one athlete played badminton only, two basketball players participated, and one swimmer was involved in the study. No cross country runners made the random sample.

Of the 11 subjects, all had participated in their sport throughout their college career regardless of their year in school. The study involved one freshman, three sophomores, four juniors, and three seniors.

Age

The athletes ranged in age from 19 to 23 years. The mean age was 20.68 years.

Height and Weight

The height of the subjects ranged from 62 inches to 71 inches. The mean height was 65.90 inches.

The weight of the subjects ranged from 115 pounds to 145 pounds. The mean weight of the subjects was 129.90 pounds.

METHODS

This study required the subjects to attend two meetings. The first meeting was for the purpose of determining each individual's maximum weight that they could lift in knee extension from 90 degrees to 180 degrees. The second meeting was when the data was collected by electromyography.

Both meetings occurred in the Lantz Training Room at Eastern Illinois University at various times between 8:00 a.m. and 1:00 p.m. The subjects were shielded from viewing of outsiders by a white curtain. The meetings were conducted in the morning before any athletic practices or activity courses to minimize fatigue entering into the study.

TESTING PROCEDURE

First Meeting

During the first meeting, each subject was tested to determine the maximum weight they could lift to full extension. The criteria which determined the maximum weight was dependent on the maximum amount of weight that each subject could extend to 180 degrees on knee extension for one performance. There were no warmup exercises conducted. The extensions were slow and controlled so that momentum could be ruled out as a factor in the knee extensions to 180 degrees. Following attainment of knee extension to 180 degrees the position was held for approximately one second.

Each subject's maximum weight on knee extension was determined through trial and error. The subject's determined verbally what their maximum weight could be so that a realistic appraisal could begin. This was a judgement decision based upon past experience. No one individual lifted weights for more than five trials in determining their maximum weight.

This study tested the subject's dominant leg. Determination of which leg was dominant was guided by the researcher. The researcher asked which leg the subject would use to kick a ball. The kicking leg was then determined to be the dominant leg.

All subjects were laying on their backs on a Universal Knee Extensor Table, model number TK-5. Their femurs were stabilized against the extensor table to minimize hip flexion by strapping the femurs against the table with a muslin wrap. The wrap encircled both femurs and the table and the ends were tied securely so as not to permit hip flexion.

Total extension during each trial was accomplished by the investigator manually stressing the knee joint into extension during the one second hold of extension. The investigator would place one of her hands on top of the femur to help stabilize it and with the other hand, she would force the lower leg into further extension. If there was further movement during this stress test, it was determined that the subject had not reached total extension herself and the weight was too heavy. The weight was either increased or decreased until the investigator was satisfied that all work to total extension with maximum weight was being performed by the subject.

After the subject's maximum weight was established, Exercise A and Exercise B was demonstrated by the researcher. The subjects were then coached by the researcher and practiced each exercise until the researcher was satisfied by their performance. The practice session was performed at each individual's one-half maximum weight.

Exercise A was practiced according to the commands within the ten seconds allotted for the exercise. The subjects were taught to move the weight slow and controlled according to the commands for each second of movement.

Exercise B was also practiced according to the commands for the exercise. The subjects were taught that Exercise B has movement throughout the ten seconds which was to be slow and controlled. The investigator emphasized to the subjects to feel the rope on the back of their legs in order to know when they had reached 15 degrees flexion during the first flexion phase of Exercise B.

Following the practice session, the procedures of the next meeting (collection of data) were explained, an appointment was determined for the next meeting and any questions that the subjects had were answered.

The first meeting lasted between 10 and 20 minutes for all subjects. Some subjects required more practice time in order to perform the exercises properly.

Second Meeting

The second meeting occurred from five to 11 days following the first meeting. This meeting involved collection of data and lasted approximately 50 minutes for each subject. In most instances, the subjects were tested two at a time. Due to scheduling conflicts, two subjects were tested individually but procedures were the same for all subjects.

Skin preparation. One of the procedures of electromyography involved insuring the electrical insulation between the muscle and electrode was at a minimum.[1] This was done by removing the dead surface layer of skin and oils by abrading the skin with fine sandpaper and cleansing the area with an alcohol solution. The skin abrasion occurred over the site of the motor point of the vastus medialis. The motor point was found by electrical stimulation by use of the Delta 330G Electrical Stimulator from the Rich-Mar Corporation of Tulsa, Oklahoma.

Placement of electrodes. The electrodes used in the study were Narco-Biosystems 710-0010 surface electrodes which were 11 millimeters in diameter. All the electrodes were prepared in the same manner before usage. The electrodes were cleaned with an alcohol solution and tested with

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[1] J.V. Basmajian, M.D., Muscles Alive, Their Functions Revealed by Electromyography, 2nd ed. (Baltimore: The Williams and Wilking Co., 1967), p. 23.

a volt-ohm-milliammeter, model number 240 from the Simpson Electric Company. The electrodes were to have registered at zero ohms in order for the testing to continue.

Double adhesive washers were then placed on the electrodes. The adhesive washers were to help keep the electrodes in place over the motor point during the testing. The adhesive washers were from Narco-Biosystems, model number 710-0013.

Electrode paste, Redux Creme, number 651-1021 from Hewlett Packard Medical Electronics was placed sparingly on the electrode which aided the electrical conduction between the muscle and electrode.

Two electrodes were placed over the area of the motor point on the belly of the vastus medialis. Inter-electrode distance was .5 centimeter. A bipolar lead was used to insure adequate monitoring of the vastus medialis throughout the entire testing session.

A third electrode which was the ground electrode was placed anterior to the medial malleolus on the dominant leg.

All electrodes were held in place with adhesive tape to minimize slipping during activity.

<u>Testing skin resistance</u>. Skin resistance was tested with the volt-ohm-milliammeter to confirm minimum resistance between the electrode and muscle. Each subject was required to reach 5,000 ohms or below in order to proceed with the

testing. Based upon current studies, 5,000 ohms was found to be an adequate goal for testing skin resistance. If this goal was not reached, the process of skin abrasion was repeated.

Electromyographic apparatus. The apparatus used in the study to record the muscle action potentials consisted of:

1. Physiograph Four, E and M Instrument Company, Incorporated, Houston, Texas.

2. Hi-gain Coupler, type 7171, Narco Bio-Systems, Incorporated, Houston, Texas.

3. Channel Amplifier, type 7070, Narco Bio-Systems, Incorporated, Houston, Texas.

4. Physiograph Pen Motor, MK V, Serial Number 2752, E and M Instrument Company, Incorporated, Houston, Texas.

5. Paper Control, Physiograph MK II, Serial Number 594, E and M Instrument Company, Incorporated, Houston, Texas.

6. Physiograph Four Recticurve Recording Paper, Narco-Biosystems, Incorporated, Houston, Texas.

7. Physiograph Red Ink, part number 713-0003, Narco-Biosystems, Incorporated, Houston, Texas.

Before each testing period, the physiograph and paper control power systems were turned on to warm up the components. The power system for the hi-gain coupler and channel amplifier was then turned on and the physiograph was calibrated at one centimeter of pen deflection = one millivolt.

DESIGN AND COLLECTION OF DATA

The research design of the study was a single-group design with two variables. Exercise A and Exercise B were the two variables which were tested at one-half maximum and three-fourths maximum weight for each exercise.

Before the first trial occurred, each subject reviewed the taped oral commands of each exercise. The purpose of this was to familiarize each subject with the mechanics of the exercises and the speed at which the exercise was performed. This was a listening review and no exercise was performed.

The exercises were tested in random order so that each exercise was tested twice for a total of eight trials. Following performance of each exercise a five minute waiting period occurred before the next exercise was tested. The five minute waiting period was to minimize fatigue entering into the study.

Each exercise was noted on the subject's recording paper of the interference pattern according to the subject, time performed, exercise performed, and trial number.

Following the collection of data, the electrodes were removed and cleaned with an alcohol solution. The subject was cleaned over the electrode site with zephrin chloride and an antiseptic ointment was placed on the abraded skin, dressed and bandaged. The subjects were instructed to return to the training room daily for antiseptic care of the abrasions to minimize infection.

STATISTICAL TECHNIQUE

The statistical treatment of the data involved the measurement of the amplitude of the spikes and counting the frequencies of the spikes on each interference pattern for each subject. Mean amplitude was then multiplied by frequency in order to obtain a quantitative figure for each trial. This quantitative score was utilized with a multiple analysis of variance program offered through the Eastern Illinois University Data Processing Center.[2,3]

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[2]Mid-Illinois Computer Co-op, version 7.0, June 27, 1977.

[3]Norman H. Nie, C. Hadlai Hull, Jean G. Jenkins, Karin Steinbrenner, Dale H. Bent, <u>Statistical Package for the Social Sciences</u>, 2nd ed. (St. Louis: McGraw-Hill Book Company, 1975).

Chapter 4

ANALYSIS OF DATA

This study employed electromyography to measure the muscle action potential of the vastus medialis during two knee extension exercises with two different loads. The study was designed to determine whether exercising the quadriceps through a full range of motion plus repetition of the last 15 degrees does increase the muscle action potential of the vastus medialis when compared to a full extension and flexion exercise.

Participating in the study were 11 female athletes from the fall and winter varsity athletic program at Eastern Illinois University. Multiple analysis of variance was utilized by the Eastern Illinois University Data Processing Center for statistical treatment.

Table 1 presents a summary of the multiple analysis of variance of the exercises, weights utilized, trials performed and exercises with various weights. Other data concerning mean amplitudes and frequencies of the interference pattern can be found in the appendix.

Exercise A versus Exercise B

Source Exercise A versus Exercise B in Table 1 represents an analysis of variance between Exercise A and Exer-

Table 1

ANALYSIS OF VARIANCE OF THE MUSCLE ACTION POTENTIAL

OF THE VASTUS MEDIALIS DURING EXERCISES A AND B

Source	ss	df	ms	F	P_o
Exercise A vs. Exercise B	13793.03	1	13793.03	1.80516	.31123
1/2 Max Weight vs. 3/4 Max Weight	196587.65	1	196587.65	25.72835*	.03674
First Trial vs. Second Trial	19407.40	1	17407.40	2.27819	.27027
Exercise by Weight	1370.28	1	1370.28	.17934	.71314

* Significant at the .05 level of confidence

cise B. There was no significant difference between performance of Exercise A and Exercise B as evidenced by an F ratio of 1.80516.

One-half Maximum Weight versus Three-fourths Maximum Weight

The differences in the amount of weight lifted as shown in Table 1 was dependent on the maximum weight that each subject could lift to full extension for one time. Each subject was tested at one-half and three-fourths of their maximum weight that they could lift. The F ratio of the differences in use of weight was 25.72835. This proved to be significant at the .05 level of confidence.

Trial One versus Trial Two

Each subject was tested for two performances or trials at each weight for each exercise. There was a total of eight trials recorded with a five minute wait between each trial. The statistical treatment compared the two trials at each weight for each exercise (example: one performance of Exercise A at one-half maximum weight versus a second performance of Exercise A at one-half maximum weight). As illustrated in Table 1, there was no significant difference between each of the trials performed at the .05 level of confidence. The F ratio for the trials was 2.27819.

Exercise by Weight

The source exercise by weight in Table 1 compared the two different exercises, Exercise A and Exercise B performed at the same weight, either one-half maximum weight or three-fourths maximum weight. The F ratio for performance of exercise by weight was .17934. This showed that there was no significant difference at the .05 level of confidence between performance of one exercise at one-half maximum weight and performance of the other exercise at the same weight.

DISCUSSION

The data agreed with the recent literature of Pocock, Lieb and Perry and Bos and Blosser concerning the lack of selective function of the vastus medialis in knee extension.[1] Overworking the vastus medialis in movement in Exercise B with the 15 degrees flexion and extension did not produce more electrical activity, thus muscle activity, than the full extension and flexion movement of Exercise A.

The data of the study did not agree with DeLorme in which he emphasized concentrating on only the last 15 degrees of extension to exercise the vastus medialis.[2] Exercise B repeated flexion and extension in the last 15 degrees and did

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[1]Ronald R. Bos, Thomas G. Blosser, "An Electromyographic Study of Vastus Medialis and Vastus Lateralis During Selected Isometric Exercises," Medicine and Science in Sports, II (Winter, 1970), p. 222; see also F.J. Lieb, J. Perry, "Quadriceps Function: An Electromyographic Study Under Isometric Conditions," Journal of Bone and Joint Surgery, LIII (June, 1971), p. 749; see also G.S. Pocock, "Electromyographic Study of the Quadriceps During Resistive Exercises," Journal of the American Physical Therapy Association, XLIII (1963), p. 433.

[2]T.L. DeLorme, "Restoration of Muscle Power by Heavy Resistance Exercises," Journal of Bone and Joint Surgery, XXVII (1945), p. 646.

not produce any more muscle action potential than Exercise A in which movement in the last 15 degrees was not emphasized. An isometric contraction occurred at full extension in Exercise A and thus movement did not occur in the last 15 degrees. Muscular activity was generated during the isometric contraction of Exercise A, however, an isotonic contraction did not occur in the last 15 degrees as it did in Exercise B.

The study was not in agreement with Wheatley and Jahnke in which their electromyographical study found the greatest activity of the vastus medialis in the last stages of the range of motion.[3] Movement of the last stages of the range of motion was emphasized in Exercise B with repetition of the last 15 degrees of extension and flexion. The data of Exercise B would have to show more muscle action potential for Exercise B when compared to Exercise A to support Wheatley and Jahnke's study. This did not occur.

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[3]M. Wheatley, W. Jahnke, "Electromyographic Study of the Superficial Thigh and Hip Muscles in Normal Individuals," Archives of Physical Medicine, (August, 1951), p. 513.

Chapter 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter will present a summary of the study, conclusions from the results of the study and recommendations based upon the conclusions.

SUMMARY

This study was undertaken to compare two therapeutic exercises in knee extension with the muscle action potential that each exercise elicited at two different work loads. One exercise (A) was knee extension from 90 degrees to 180 degrees with a four second hold at 180 degrees and followed by flexion to 90 degrees. The other exercise (B) was extension from 90 degrees to 180 degrees, 15 degrees flexion, 15 degrees extension and flexion to 90 degrees.

The importance of comparing each exercise and the different work loads lies in the selection of therapeutic exercises for efficient rehabilitation of the knee and particularly the vastus medialis.

Varsity female athletes from the fall and winter interscholastic athletic program at Eastern Illinois University served as subjects for the investigation. The 11 subjects were randomly selected.

Electromyography was used to measure the muscle action potentials as the subjects performed each exercise at the varying weights as required. Each athlete was tested on Exercise A and Exercise B at one-half and three-fourths maximum weight that they could lift to full extension at two trials for each exercise at each weight.

Interference patterns were measured by counting frequencies and measuring amplitude of spikes. Mean amplitude was multiplied by frequency and this quantitative figure was computed by the Eastern Illinois University Data Processing Center by a multiple analysis of variance program.

CONCLUSIONS

The study concluded that:

1. There is no difference in the muscle action potential of an exercise requiring full extension and flexion as compared with an exercise requiring full extension, 15 degrees flexion, 15 degrees extension and full flexion when each exercise is performed in 10 seconds with the same amount of weight.

2. There is a difference in the muscle action potential of performance in knee extension of one-half maximum weight that the athlete can lift and performance of three-fourths maximum weight that the athlete can lift. Knee extension with three-fourths maximum weight elicited more electrical activity than knee extension with one-half maximum weight.

3. A five minute interval between performances of

Exercise A and Exercise B including the varying weights of one-half maximum weight lifted and three-fourths maximum weight lifted does not have a tiring effect on the vastus medialis. Therefore, fatigue can be discounted as a factor in the results of the study.

RECOMMENDATIONS

It is recommended for movement in knee extension that Exercise A would be financially practical to utilize. Although there was no difference in the muscle action potential between the two exercises, Exercise A required less apparatus and less kinesthetic coordination to accomplish. In Exercise B a 15 degree slant board was constructed and the athlete had to feel where in the range of motion 15 degrees flexion was with the assistance of another person. Exercise A can be practiced by the athlete alone and requires the use of only a knee extension table.

Since work equals force multiplied by distance, Exercise B would produce more work because of the addition of the 15 degrees flexion and extension. An additional study would be required to determine the value of the four second hold in Exercise A as compared to the 15 degrees flexion and extension phase of Exercise B. Perhaps through research, the optimum time to hold the weights at full extension could be discovered for quadriceps femoris exercises.

It is recommended that this study be repeated with different variables. The use of different loads should be studied. This investigation employed only two different loads, one-half maximum weight and three-fourths maximum weight. A study is needed to investigate the value of different work loads on the muscle action potential of the vastus medialis. Numerous work loads ranging from a small amount of weight up to the maximum weight should be studied.

The study should also be repeated using similar subjects, conditions and variables in order to validate the present study.

A recommendation is that the study be repeated on subjects following an injury to determine the effect of each exercise on the muscle action potential of the vastus medialis during the rehabilitation period following an injury to the knee. This may vary results which could be very significant in rehabilitating the injured knee.

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APPENDIX A

RESULTS OF THE MEASUREMENTS

OF THE MEAN AMPLITUDE AND FREQUENCY

OF THE VASTUS MEDIALIS - EXERCISE A, 1/2 MAXIMUM WEIGHT

Subject	Trial	Mean Amplitude	Frequency	Mean Amplitude x Frequency
1	1	1.36	206	280.16
	2	1.61	228	367.08
2	1	1.08	172	185.76
	2	1.09	180	196.20
3	1	1.60	227	363.20
	2	1.17	197	230.49
4	1	1.81	244	441.64
	2	2.03	263	533.89
5	1	0.87	207	180.09
	2	0.96	204	195.84
6	1	1.02	256	261.12
	2	1.10	239	262.90
7	1	1.23	212	260.76
	2	1.43	204	291.72
8	1	0.98	199	195.02
	2	0.94	206	193.64
9	1	0.97	192	186.24
	2	0.91	165	150.15
10	1	1.75	258	451.50
	2	2.32	244	566.08
11	1	2.32	250	580.00
	2	2.08	246	511.68

Mean: Trial 1 = 307.77 S.D.: Trial 1 = 134.01
Trial 2 = 318.15 Trial 2 = 152.60

APPENDIX B

RESULTS OF THE MEASUREMENTS

OF THE MEAN AMPLITUDE AND FREQUENCY

OF THE VASTUS MEDIALIS - EXERCISE A, 3/4 MAXIMUM WEIGHT

Subject	Trial	Mean Amplitude	Frequency	Mean Amplitude x Frequency
1	1	1.80	232	417.60
	2	1.71	259	442.89
2	1	1.41	218	307.38
	2	1.30	200	260.00
3	1	1.61	244	392.84
	2	1.28	241	308.48
4	1	2.18	258	562.44
	2	2.28	239	544.92
5	1	1.69	268	452.92
	2	1.07	226	241.82
6	1	1.99	258	513.42
	2	1.69	251	424.19
7	1	1.86	218	405.48
	2	1.69	228	385.32
8	1	1.27	221	280.67
	2	0.93	181	168.33
9	1	0.78	163	127.14
	2	0.78	153	119.34
10	1	1.75	289	505.75
	2	1.65	257	424.05
11	1	3.16	283	894.28
	2	2.21	279	616.59

Mean: Trial 1 = 441.81 S.D.: Trial 1 = 193.90
Trial 2 = 357.81 Trial 2 = 153.95

APPENDIX C

RESULTS OF THE MEASUREMENTS

OF THE MEAN AMPLITUDE AND FREQUENCY

OF THE VASTUS MEDIALIS - EXERCISE B, 1/2 MAXIMUM WEIGHT

Subject	Trial	Mean Amplitude	Frequency	Mean Amplitude x Frequency
1	1	1.13	192	216.96
	2	1.03	189	194.67
2	1	1.35	207	279.45
	2	1.15	172	197.80
3	1	1.19	182	216.58
	2	0.88	162	142.56
4	1	2.13	256	545.28
	2	2.11	227	478.97
5	1	1.43	272	388.96
	2	1.00	234	234.00
6	1	1.19	280	333.20
	2	1.30	231	300.30
7	1	1.34	199	266.66
	2	1.46	218	318.28
8	1	0.76	150	114.00
	2	0.82	168	137.76
9	1	0.94	176	165.44
	2	0.78	146	113.88
10	1	1.33	232	308.56
	2	1.36	235	319.60
11	1	2.31	259	598.29
	2	2.64	250	660.00

Mean: Trial 1 = 312.13 S.D.: Trial 1 = 149.90
Trial 2 = 281.62 Trial 2 = 164.40

APPENDIX D

RESULTS OF THE MEASUREMENTS
OF THE MEAN AMPLITUDE AND FREQUENCY
OF THE VASTUS MEDIALIS - EXERCISE B, 3/4 MAXIMUM WEIGHT

Subject	Trial	Mean Amplitude	Frequency	Mean Amplitude x Frequency
1	1	1.61	238	383.18
	2	1.51	253	382.03
2	1	1.73	226	390.98
	2	1.42	213	302.46
3	1	1.20	206	247.20
	2	1.32	206	271.92
4	1	2.25	258	580.50
	2	2.57	253	650.21
5	1	1.02	238	242.76
	2	1.03	209	215.27
6	1	1.77	274	484.98
	2	1.80	241	433.80
7	1	1.83	233	426.39
	2	1.84	214	393.76
8	1	0.98	183	179.34
	2	0.95	189	179.55
9	1	0.89	168	149.52
	2	0.69	144	99.36
10	1	1.51	235	354.85
	2	1.50	236	354.00
11	1	2.67	259	691.53
	2	2.35	270	634.50

Mean: Trial 1 = 375.57 S.D.: Trial 1 = 167.58
Trial 2 = 356.08 Trial 2 = 172.92

APPENDIX E

DATA CHART FOR DOMINANT LEG AND WEIGHT MEASURED

Subject	Dominant Leg	Maximum Weight*	1/2 Maximum Weight*	3/4 Maximum Weight*
1	Right	40	20	30
2	Right	30	15	22.5
3	Right	35	17.5	25
4	Left	30	15	22.5
5	Right	30	15	22.5
6	Right	40	20	30
7	Right	30	15	22.5
8	Right	25	12.5	17.5
9	Right	20	10	15
10	Right	25	12.5	17.5
11	Right	40	20	30

* Pounds

APPENDIX F

DATA CHART OF SUBJECTS

Subject	Age (years)	Height (inches)	Weight (lbs.)
1	22.08	71	145
2	19.75	68	130
3	19.08	68	135
4	23.25	62	115
5	21.00	67	135
6	20.58	68	145
7	21.16	67	120
8	21.66	62	123
9	19.66	64	135
10	20.00	63	130
11	19.33	65	116

VITA

Janet Jean Lozar was born on December 16, 1951 in Sussex, New Jersey. She attended Sussex Grammar School and High Point Regional High School which are both in Sussex, New Jersey. She majored in College Preparatory in high school and graduated from there in June of 1970. While in high school, her major activities included participation in all phases of the girl's athletic program and band. Awards given to her in high school consisted of Most Valuable Girl Athlete Award and Booster Club Scholarship in June, 1970.

She received her Bachelor of Science degree in Health, Physical Education and Recreation from Lock Haven State College, Lock Haven, Pennsylvania in May, 1974.

From December, 1974 to June, 1977 she taught physical education on the secondary level in Linwood, New Jersey. She also coached girl's basketball, field hockey, tennis, and track and field. Coaching credits include Assistant Coach of South Jersey (Sectional) Girl's Basketball Championship Team and Assistant Coach of New Jersey State (Finals) Field Hockey Championship Team.

From August, 1977 to April, 1978 she was Assistant Athletic Trainer at LaSalle College, Philadelphia, Pennsylvania.

From June, 1978 to June, 1979 she was a Graduate Assistant in Athletic Training at Eastern Illinois University where she will receive a Master of Science degree in Physical Education in August, 1979.

Currently she is looking for employment on the college level as an athletic trainer.