Electromyographic Studies on Some of the Muscles Involved in Rotation of the Leg

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ELECTROMYOGRAPHIC STUDIES ON SOME
OF THE MUSCLES INVOLVED
IN ROTATION
OF THE LEG

by

John A. Boczkievicz

A Thesis Submitted to the Faculty of the Graduate School
of Loyola University in Partial Fulfillment of
The Requirements for the Degree of
Master of Science

June
1953
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This problem would have been long delayed without the aid of my colleague, Mr. Leo F. Stock who contributed unselfishly of his time.
LIFE

John A. Boczkiewicz, Jr. was born in Galatia, Illinois, August 30, 1926.

He was graduated from Galatia Community High School, Galatia, Illinois, May 1, 1944.

He served in the Army of the United States from December 6, 1944 to February 12, 1947.

From March 1947 until August 1950 he studied at Southern Illinois University, Carbondale, Illinois and the University of Illinois at Urbana. He received the Bachelor of Arts Degree from Southern Illinois University in August 1950.

In September, 1951, he began his graduate studies at Loyola University.
CHAPTER I

INTRODUCTION

Man has long been fascinated by movements of all animals and especially by the movements of the human body. Much speculation and discussion has arisen over animal movement, from the pseudopodic movement of the Amoeba to the complex movements of mammals which frequently involve many muscles moving over more than one joint. In almost any classical textbook of anatomy one can find that the muscular and skeletal systems are said to give support to, and bring about locomotion of the body. The bones of the axial and appendicular skeleton provide the levers for bodily movement, while the muscles exert the force that moves the levers. It is not infrequent that one is left with the idea that these two systems are all that is needed for the locomotion of the human body. Like any type of work done by a system of levers, locomotion of the human body requires fulcra for its leverage system. The fulcra of body locomotion which are often treated lightly by the anatomist, in relation to the muscular and skeletal systems for locomotion, are located in the joints of the body. The clinician is well aware of the impairment to locomotion when there is damage to a joint, so in the study
of locomotion or any muscular movement of bones it is well
to keep in mind the anatomy of the fulcra or joints about
which the movement is made. The description given in Morris'
textbook of anatomy, 10th edition, for the knee joint has been
confirmed by the author on knee joints of five cadavera and
will suffice for the explanation of all movements studied in
this problem.

Myology has evolved from a simple and inaccurate
science, to the more complex and much more accurate science
that we know today.

One of the earliest methods employed in myology was
a study of the origin, direction of fibers, and insertion of
muscles. This method resulted in many false interpretations
as to the action of muscles. No doubt one of the chief diffi-
culties with this method was the failure to recognize syner-
gistic muscles, especially when they were covered by the prime
mover or other muscles. Within limitations this method has
served as the basis for much of our present knowledge of
myology.

The above method led to much observation of muscle
action in the living organism. This observation of movement
proved to be an advancement over the study of muscles in the
cadaver. With this method the myelogist began to realize that
a particular action was not confined to a single muscle, but
many muscles could act synergistically to produce a single
movement.

Paralysis of muscles has been utilized in determining the action of a given muscle or group of muscles. Paralysis has been studied in disease as well as by experimental blocking of the nerve supply. The movements affected by the paralysis can be directly correlated with the muscle or muscles paralyzed. This does not always tell us if a muscle is a synergist for a movement that might have been impaired, but it definitely indicates prime movers.

Erlanger (1922) introduced a new technique for the study of muscle action. He used the Cathode Ray Oscilloscope to record action potentials produced by the transmission of a nerve impulse which causes the contraction of striated muscle. Later workers developed pen-writing recorders in order to obtain permanent records of these potentials. When this technique is applied to muscle study it is known as electromyography.

Muscle contractions result from definite potential differences that can be detected and recorded. Such an apparatus is known as an electromyograph. It consists of electrodes for picking up the action potentials and an amplifier where the potential is stepped-up sufficiently to cause the movement of an electromagnet which is hooked to an ink-writer which records the electromyogram. The ink-writer can be replaced with an oscilloscope or myoscope to obtain the potential change. Precisely, we can say that an electromyograph is an
instrument which records the electrical activity associated with the contraction of a striated muscle fiber. Thus, the action potentials produced by a muscle are an indication of the qualitative action of the muscle, when action is defined as the depolarization of muscle.

Electrodes for recording action potentials are essentially of two types, unipolar and bipolar. Bipolar electrodes, i.e. two active electrodes, record the difference in potential between the two electrodes. Unipolar electrodes, consist of one active or exploring electrode, and one indifferent or inactive electrode. The inactive electrode is made so by placing in its circuit a resistance of enough ohms to prevent any activity being picked up at its site. So the unipolar electrode technique differs from the bipolar in that it does not record differences in potential between the exploring and indifferent electrode, but records the activity that the exploring electrode faces. When using either the bipolar or unipolar electrode technique both surface and needle electrodes may be utilized. Surface electrodes consist usually of a metal disk placed on the skin over the muscle to be studied. The size of the disk varies with the muscle or groups to be studied. Needle electrodes consist of a needle insulated except at the tip. The needle is inserted directly into the muscle to be studied. This allows the study of single motor units.

The motor unit, consisting of a single motor neuron
together with the muscle fibers which it innervates, is the physiological unit of muscle action. All the muscle fibers of the motor unit contract approximately simultaneously. When a muscle contracts more forcibly, more motor units are involved and their rate of discharge is higher. This means that more unitary action potentials can be detected in the electrical record and higher rates of discharge observed for the different units. Electrical potential changes invariably accompany contraction in a normal muscle. Conversely, when no action potentials can be detected in muscle, the muscle is at rest, or completely relaxed. Complete relaxation of most muscles can usually be achieved voluntarily. With the use of very sensitive equipment, Besma and Gellhorn (1946) have recorded potentials from resting muscle. They did not consider these true action potentials but probably the result of the nerve impulses which maintain muscle tone. Such potentials help explain the control a motor nerve has over the muscles it innervates. Major changes in activity known as fibrillations and fasciculations occur when the influence of the motor nerve is damaged between the anterior horn cells and the muscle. The dependence of a muscle on its motor nerve has long been recognized by investigators in the field of anatomy. The great comparative anatomist, Dr. Libbie H. Hyman (1946), relates muscle and nerve as follows, "skeletal muscle is the end organ of a motor nerve". This statement alludes to the important
relation between the muscular and nervous systems in the animal organism.

Adrian and Bronk (1929) removed from speculation the relation between the number of impulses traversing a motor nerve fiber and the number of action potentials produced by a motor unit. They reported on the frequency of discharge in reflex and voluntary contraction. Using concentric bipolar needle electrodes they discovered that single motor unit discharges agree with the discharges from the single nerve fiber. As muscle contraction increases there is an increase in the frequency of discharge of one motor unit as well as an increase in the number of units in action. During voluntary contraction of a motor unit the impulses recorded by the electromyogram are composed of rhythmic discharges. Different groups of muscle fibers vary in their frequency of discharge, depending on the strength of the contraction. This results in an arrhythmic volley of impulses from a muscle during contraction.
CHAPTER II

PROCEDURE

A. Materials

The materials used in this experimentation consisted of an apparatus for measuring rotation at the knee joint, and equipment for the detection and recording of potentials associated with the muscular activity involved in rotation of the leg while flexed at an angle of 90°.

For measuring the amount of rotation at the knee joint an ordinary laboratory steel was provided with a foot form by driving nails into the platform of the stool. Below the platform of the stool and extending about three inches beyond the edge of the stool was placed a plywood board marked in degrees in order to measure the amount the stool was rotated from a given point. With this apparatus the amount that each subject could rotate his leg either medial or lateral was recorded. (Fig. 1)

Three types of apparatus were used for the detection and recording of potentials. The work was originally started on a six channel Grass Type Electroencephalograph adapted for electromyographic recordings. The apparatus consisted of a sixteen source pick-up box, with leads to the electrodes which were placed over the muscles under study. From the pick-
up box the potentials were sent to a six channel preamplifier. Any two of the electrodes going into the pick-up box could be channeled to any one or all six of the channels on the preamplifier. This made it possible to take six simultaneous recordings from any one muscle or six simultaneous readings from six different muscles. From the preamplifier the potentials were carried to an amplifier. Each of the channels on the preamplifier represented a channel on the amplifier.

From the amplifier the potentials were fed to the ink-recording portion of this equipment. This consisted of electromagnets which received the potentials. The electromagnets were connected directly to the ink-writers. The changes in magnitude and duration made by the ink-writers can be correlated with a change in intensity and strength of action potentials from the muscles under study. Several surveys of the muscles to be studied were made with this instrument. The work was then repeated on the next instrument to be discussed. The using of the second machine was made necessary by the fact that the ink-writing portion of the Grass instrument functioned inefficiently, and needed constant repairs which made the recording of permanent records very difficult. The Grass instrument did not have internal grounds adequate to prevent interference of 60 cycle house current and other interference that might be in the room. The grounded wire cage constructed to prevent this interference did not function sufficiently in
this capacity. The great advantage of this instrument was its multiple channels and its sensitivity. Pictures of the cage and instrument are shown in figures one and two.

The second instrument used was a Sanborn Poly Viso Electrocardiograph. This instrument was essentially the same in operation as the instrument previously described. The different components of this instrument from the pick-up box to the writing arms were housed in one unit which simplified the work from the standpoint of ease in operation. This instrument had sufficient internal grounds which made the use of the wire cage unnecessary. The disadvantages of this instrument were that it had only four channels, and electrodes that were non-adjustable in size. The advantages of the machine were ease in operation, compactness, portability, thermo-ink-writers, and the internal ground which did away with the use of the wire cage. The information gained from the Grass instrument was confirmed on this instrument and permanent records made. This instrument (Fig. 3) was made available through the courtesy of the Department of Physiology, Stritch School of Medicine, of Loyola University.

The other instrument used in this work was a Meditron Electromyograph made by the Meditron Company of Pasadena, California. The great advantage of this instrument was its sensitivity, plus the fact that a myoscope or magnetic tape recorder allowed recording of potentials which could be played
back on the oscilloscope screen at any time. This instrument could be calibrated to measure accurately the potentials produced. The main disadvantage of this instrument was that it had only one channel hence only one muscle at a time could be studied. Dr. Y.T. Oester, of the Department of Pharmacology, Loyola University, made this instrument (Fig. 4) available for this work.
B. Methods

Fourteen students of Loyola University varying in age from twenty to twenty-three were used in this study. The procedure using each machine will be described separately.


All of the permanent recordings reproduced in this thesis were made with this instrument. Before beginning the experiment the subjects were instructed in the general procedure. This included describing the proper position for the subjects, and the movements they would execute. With the leg flexed at an angle of 90° and the foot in the footplate of the recording apparatus, the movements were explained as follows. The first movement to be made is normal (unforced) lateral rotation. The next movement will be forced lateral rotation; this is to move the foot from the position of normal lateral to as far laterally as possible. In this movement it is essential that no motion occur at the ankle joint, but that all movements take place at the knee joint. The next movement is to bring the foot back to the zero position. The zero position means where the foot feels the most comfortable for the individual. This does not necessarily coincide with the original starting position. The individual was then instructed that the next movements would be medial rotation. The first movement here would be normal medial rotation. It was explained
at this time that medial rotation would be much less than lateral so that one should not force the movement. The next movement is forced medial rotation--this being the same as lateral in the opposite direction. The final movement of each series is back to the zero position from forced medial rotation.

The subject after having the opportunity to ask questions about or have any of the movements demonstrated was instructed to place his feet on the recording apparatus for a practice run. The subject was then given the following instructions--normal lateral rotation--forced lateral rotation--back to zero--normal medial rotation--forced medial rotation--back to zero. Following each movement and before instructions were given for the next, a reading was taken of the range of movement in the individual.

The electrodes were then placed on the muscles to be studied. Skin resistance was decreased by the use of "Redux", a common electrode jelly. One of the workers would operate the electromyograph and give the instructions to make the desired movements. The other worker would observe the recording apparatus and designate on the record when a particular movement had been completed. Then instructions could be given for the next movement. At the beginning and end of each movement a notation was made on the electromyogram so that the action potentials could be interpreted for each movement.

2. Procedure using the Grass Electroencephalograph.
This procedure was essentially the same as far as the movements that are concerned. The subjects were placed in the wire cage while recording to prevent interference. No permanent records were made with this instrument, but the recording apparatus gave essentially the same results as were obtained with the instrument previously described. This instrument proved to be a valuable confirmation tool due to its sensitivity. Silver electrodes one centimeter in diameter attached by the use of scotch tape were used with this instrument.

3. Procedure using the Meditron Electromyograph.

With this instrument the permanent records were made on a magnetic tape recorder. This makes it possible to see them played back on an oscilloscope or hear them through a loud speaker at any time. While making permanent recordings on the magnetic tape, temporary records were recorded on an oscilloscope incorporated in this machine. The electrodes used with this instrument were of the same type as used with the Grass instrument. On a second check with this instrument needle electrodes were placed directly into each muscle to check the results obtained with the surface electrodes.
CHAPTER III

Experimental Results (Figures 5-10)

Activity of Individual Muscles

1. Biceps Femoris. This muscle produced action potentials during all movements studied, listed from greatest to least.

1. Forced lateral rotation
2. Normal lateral rotation
3. Back to zero from forced medial
4. Forced medial rotation
5. Normal medial rotation
6. Back to zero from forced lateral

2. Semimembranosus and Semitendinosus. This muscle pair was studied together, since with surface electrodes it would have been difficult to distinguish between the two muscles. Their activity—from greatest to least—is as follows.

1. Forced lateral rotation
2. Normal lateral rotation
3. Forced medial rotation
4. Back to zero from forced medial
5. Back to zero from forced lateral
6. Normal medial rotation

3. Gracilis. This muscle also showed activity in all of the movements concerned. The pattern of activity was the same as the other two medial rotators discussed above.

1. Forced lateral rotation
2. Normal lateral rotation
3. Forced medial rotation
4. Back to zero from forced medial
5. Back to zero from forced lateral
6. Normal lateral
4. Sartorius. This muscle, ordinarily considered a medial rotator, failed to show any appreciable activity in any of the medial movements. It was completely inactive in some of the medial movements. Surprisingly its greatest activity was in lateral rotation. The order of activity of this muscle is as follows.

1. Forced lateral rotation
2. Normal lateral rotation
3. Back to zero from forced medial
4. Normal medial rotation (small activity)
5. Back to zero from forced lateral (very small activity)
6. No activity in forced medial

5. Tensor Fascia Lata. The activity was in the following order.

1. Forced lateral rotation
2. Normal lateral rotation
3. Back to zero from forced lateral
4. No activity in normal medial rotation
5. No activity in forced medial rotation
6. No activity in the movement back to zero from forced medial

6. Popliteus. This muscle due to its inaccessibility presented a major problem. Potential changes were successfully recorded only with the Meditron Electromyograph. Consequently, there is only one permanent record from this muscle instead of two as with all of the rest.

1. Forced medial rotation
2. Normal medial rotation
3. Back to zero from forced lateral
4. No activity in normal lateral rotation
5. No activity in forced lateral rotation
6. No activity in the movement back to zero from forced medial rotation
If we look at the results obtained from the superficial medial rotators as a group, we find one thing consistent. These medial rotators produce more action potentials during lateral movements than they do during medial movements.

The one deep medial rotator studied (Popliteus) does not give similar results to those obtained from the superficial medial rotators. This muscle produced action potentials while performing medial movements, but showed no potential changes during lateral rotation.

Of the two lateral rotators studied each gave results that were quite different. The Biceps Femoris produced action potentials in all of the movements studied. The greatest amounts of potentials produced was in lateral movements. Forced lateral produced the highest amount of activity, followed by normal lateral and then by the movement back to zero position from forced medial rotation. During medial movements the action potentials produced were smaller in amounts than those produced during lateral movements. The Tensor Fascia Lata produced potential changes in only three of the six movements studied. Two of the movements were lateral movements and one was a medial movement. The greatest amount of potential changes were seen in forced lateral rotation, followed by normal lateral rotation. The only other activity which was recorded was a small amount which occurred from the movement back to zero position from forced lateral rotation.
CHAPTER IV
DISCUSSION

Much has been said concerning the electrical potentials that are associated with a shortening contraction of muscle or muscle fibers. The early work in the field of electromyography was concerned with the potentials produced by a shortening muscle, because it is the shortening of a muscle that obviously accomplishes work. Later experimental work in the field of electromyography has caused a review of some of the basic principles of muscle physiology. We now look to muscles that are not shortening for the production of action potentials, as well as muscles that are shortening. To extend these concepts a bit further, in many cases we are also concerned with muscles that are giving off action potentials while lengthening. So much has been written about the production of action potentials by shortening muscles that many assumed that only shortening muscles produced action potentials. However, as was pointed out previously in this paragraph, this is not true. Action potentials are not dependent upon the shortening of a muscle, but are produced by the phenomena we know today as depolarization. Depolarization occurs not only in muscle that are shortening but in muscles while lengthening or neither shortening or lengthening.

Depolarization gives rise to action potentials which
are recorded by two methods. These methods are dependent upon the type of electrode used to record the potential. If the bipolar type of recording is used the electrical changes causing the action potentials is measured by determining the difference in potential between the two electrodes. If the unipolar technique of recording is used, the action potentials are determined by the electrical nature of the tissue that the active electrode is facing during the recording. If the active electrode is facing "negativity" by convention most electrical recording equipment such as electromyographs and electrocardiographs will record above the baseline. If the active electrode is facing "positivity" in relation to the surrounding tissue the recording device will write below the baseline. We can say without a doubt, that any electrical changes produced in a muscle will be recorded if the recording equipment is of the proper type, i.e. sensitive enough, and the electrode is properly placed.

Potential changes that accompany isometric contraction of a normal muscle are of the same nature as those with isotonic contraction. In isometric contraction we mean the production of action potentials and activity without shortening of muscle fibers.

Myotatic contraction is defined as "contraction brought about by the sudden stretching of a muscle". An example of this would be seen in a sudden extension of the leg from tapping
the patellar tendon,—the knee jerk. This myotatic contraction could be detected by recording the action potentials either by needle electrodes in the muscle or surface electrodes on the skin over the muscle. We should introduce into electromyography a new concept, of the myotatic reflex as a result of the phenomena observed by several workers in this field during the past few years. The phenomena to be described is that of action potential production by a muscle that is gradually increasing its length. This myotatic reflex can be brought about by different means. One method is by the electrical change of a gradual lengthening muscle as a result of the contraction of its antagonist. We see this particular action in the Semimembranosus and Semitendinosus when the leg is laterally rotated while flexed at an angle of 90°. Previous workers in this field whose results have shown this phenomena of the myotatic reflex have studied a variety of muscle groups. Mortenson and his group (1948) from Wisconsin in their work on the muscle Biceps Brachii showed this myotatic reflex with or without a load to increase the amplitude of the impulses. In similar work Kabat and Levine (1952) showed this phenomena in the Anterior Tibialis, Gastrocnemius, as well as the Biceps and Triceps Brachii. Pauly and Beargie (1952) from this institution showed this phenomena of the myotatic reflex in their work on the muscles of respiration. In this work the muscle Scalenus Anterior was shown to discharge action potentials
in both inspiration and expiration. By the very obvious movements produced here it can be readily seen that in inspiration and expiration this muscle will shorten in one of the actions and lengthen in the other.

The actual increase of potentials from gradually stretching muscle is different from the reciprocal innervation described by Sherrington in which the antagonistic muscles are inhibited. An explanation for this is that the lengthening muscles are trying to stabilize the joint.

The original plan for this investigation was to measure quantitatively the action potentials produced by the muscles involved in rotation of the leg. It was thought that this work would reveal the amount that each muscle was involved in rotating the leg medially and laterally. It was also hoped to measure the amount of activity for any given degree of movement medially or laterally. After studying the electromyographic phenomena, this plan was changed. It is considered impossible as yet to measure muscle activity quantitatively.

The new problem undertaken was to study some of the muscles involved in medial and lateral rotation of the leg. The results of this study was presented in the previous chapter. The muscles of the study will be discussed individually. An attempt to elucidate the results for every movement will be made.

1. Biceps Femoris. This muscle produced action poten-
tials in every movement studied. Since the muscle is classified as a lateral rotator, it is easily understood why a potential change would be recorded during a lateral movement. A normal and a forced medial rotation would place a stretch on the muscle. Activity during this stretch would tend to stabilize the knee joint, preventing it from making a rapid jerk medially. The potential changes associated with the stretching of the Biceps Femoris are presumably due to a myotatic reflex. Potential changes that caused the medial movement of going back to the zero position from forced lateral rotation may also be explained by myotatic reflex. To summarize the action produced by this muscle we could say; shortening and potential changes are brought about through the action of its motor nerve in all of the lateral movements. The normal and forced medial rotation brought about lengthening, initiating a myotatic reflex. The medial movement back to the zero position from forced lateral rotation also caused potential changes by lengthening. This lengthening of the Biceps Femoris was caused by the contraction (shortening) of the medial rotators.

2. Semimembranosus and Semitendinosus. This muscle pair also produced action potentials in both lateral and medial movements. The medial movements like any movement caused by shortening of a muscle would be accompanied by potential differences in the tissue. The lateral movements produced great-
er potential changes than did the medial movements. This raises the question, is this pair of medial rotators more active in lateral than in medial rotation of the leg? From the experimental evidence obtained, we can give this answer. It appears that the potential changes produced by stretching due to the lateral movements is greater than which accompanies shortening in medial movements. This is true for the locations recorded in this work; however, it may not be true for the whole muscle mass. It is felt with our knowledge today that it would be impossible to measure the absolute activity of a given muscle by the use of surface electrodes.

3. Gracilis. This muscle showed the same qualitative activity as the Semimembranosus Semitendinosus pair. The same explanation for this activity can be offered as was given for those muscles. This muscle was studied in more locations than any of the other muscles. Its qualitative results were the same from all locations and from all individuals studied. This gives support to the possibility that there are more absolute potential changes produced from the stretching of lateral rotation than during the shortening of medial rotation.

4. Sartorius. This muscle failed to show any appreciable activity during medial movements. This held true for various sites over the muscle. When first observed it was a disturbing result since the muscle is classified as a medial
rotator. However, easily recordable potential changes occurred during the lateral movements. Here again is evidence that more electrical activity occurs from stretching of the muscle than from shortening of the muscle which should aid in medial rotation. We must assume from the failure to record potential changes during medial rotation that this muscle exerts no effect during medial rotation.

6. Tensor Fascia Lata. This muscle showed no activity during voluntary medial rotation, but during the medial rotation to the zero position from forced lateral rotation potential changes were recorded. This indicates that there was insufficient potential change during medial movement to be recorded from the skin over this muscle. The activity recorded in normal and forced lateral rotation is in accord with the potential changes resulting from the shortening of the muscle. The lateral movement of returning to the zero position from forced medial rotation produced no recordable potential changes.

6. Popliteus. This muscle was studied with only one of the instruments for reasons previously mentioned. This muscle produced recordable potential changes on medial rotation associated with a shortening of its fibers. The production of such activity has been explained for other muscles of this study. No potential changes resulted in the stretching of this muscle.
Before terminating this discussion an attempt to resolve one problem is in order. From observing the electromyograms and reading the results of this work, one sees that all of the superficial medial rotators produce greater potential changes during lateral rotation than they do during medial rotation. This is not true of the lateral rotators. They produce greater potential changes during lateral rotation than during medial rotation. A possible answer for this lies in the fact that normal lateral movements are double those of normal medial movements and forced lateral movements are seventy-five per cent greater than the forced medial movements. This means that the medial rotators during lateral rotation have to stretch much more than they have to shorten during the medial movements. Consequently, the lateral rotators have to shorten more during lateral rotation than they have to lengthen during medial rotation.

In analyzing further we see there are three types of response in these muscles.

1. Muscles more active during lengthening—i.e. Gracilis, Semimembranosus—Semitendinosus, and Sartorius.

2. Muscles more active during shortening—i.e. Tensor Fascia Lata and Biceps Femoris.

3. A muscle active only during shortening—i.e. the Popliteus.

It seems reasonable to consider that the activity during
lengthening depends on factors other than lengthening per se, such as the type of joint, the stability of the joint, the stress around the joint, and the postural adjustments required. It may be that under differing circumstances one muscle may be able to exhibit more than one of these types of activity. Such a hypothesis should be tested in further research.
CHAPTER V

SUMMARY

1. Six muscles were studied electromyographically to determine their state of activity during rotation of the leg. The muscles studied were: the Biceps Femoris, the Tensor Fascia Lata, the Semimembranosus-Semitendinosus pair, the Gracilis, the Sartorius, and the Popliteus.

2. Records were made from each muscle during the following movements: normal lateral rotation, forced lateral rotation, back to the zero position from forced lateral rotation, normal medial rotation, forced medial rotation, back to the zero position from forced medial rotation.

3. Records were made with three recording instruments, a Grass model Electroencephalograph, adapted for electromyographic purposes, a Sanborn Poly Visual Electrocardiograph, and a Meditron Electromyograph with an incorporated myoscope.

4. During normal lateral rotation all muscles except the Popliteus showed activity. The greatest activity was shown by Biceps Femoris and the Semimembranosus-Semitendinosus pair, followed by the Gracilis, Sartorius, and the Tensor Fascia Lata.

5. In forced lateral rotation again all muscles except the Popliteus showed activity. The Biceps Femoris showed the greatest amount of activity; the Semimembranosus-Semitendinosus pair and Gracilis second with approximately the same amount of
activity; the Tensor Fascia Lata and the Sartorius showed slightly less activity than the other muscles.

6. In the movement back to the zero position from forced lateral rotation all muscles showed activity. The lateral rotator the Biceps Femoris showed the greatest amount of activity. Again the Semimembranosus-Semitendinosus pair and the Gracilis were second. The deep medial rotator the Popliteus produced the next greatest amount of activity. The Sartorius and Tensor Fascia Lata produced activity that was barely detectable.

7. In normal medial rotation the Tensor Fascia Lata showed no activity. A medial and a lateral rotator showed the greatest amounts of activity, namely the Popliteus and Biceps Femoris. The Semimembranosus-Semitendinosus pair, the Gracilis, and the Sartorius all showed approximately equal but very slight activity.

8. In forced medial rotation a medial rotator the Sartorius, and a lateral rotator the Tensor Fascia Lata failed to show activity. The other four muscles studied showed activity of approximately equal amounts.

9. In the lateral movement of back to the zero position from forced medial rotation the Tensor Fascia Lata and the deep medial rotator, the Popliteus, showed no activity. The superficial lateral rotator the Biceps Femoris showed the greatest amount of activity. Of those showing any action
at all the Sartorius showed the least amount. The Gracilis and Semimembranosus-Semitendinosus pair showed approximately equal amounts of activity.

10. All of the medial rotators studied except the Popliteus were more active during lateral rotation than during medial rotation. The Popliteus was active only during medial rotation. The lateral rotators showed more activity during lateral rotation than during medial.

11. From this study we see that there are at least two methods of producing action potentials in muscle. They can be initiated through mechanical means such as the pull of another muscle (which stimulates proprioceptive receptors and reflexly initiates nervous stimuli to the muscle), or through voluntary means by the influence of its motor nerve.

12. There has not been developed to date instruments or technical information that will allow one to measure the absolute electrical activity from a given muscle or muscle mass during a given movement.
BIBLIOGRAPHY


### TABLE I

**Voluntary Lateral Movements**

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<thead>
<tr>
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<tbody>
<tr>
<td>Biceps Femoris</td>
<td>Strong activity</td>
<td>Very strong activity</td>
</tr>
<tr>
<td>Semimembranosus-</td>
<td>Strong activity</td>
<td>Very strong activity</td>
</tr>
<tr>
<td>semitendinosus</td>
<td>Strong activity</td>
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</tr>
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<td>Gracilis</td>
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<td>Sartorius</td>
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<td>Moderate activity</td>
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<tr>
<td>Tensor Fascia Lata</td>
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<td>Strong activity</td>
</tr>
<tr>
<td>Popliteus</td>
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<td>No activity</td>
</tr>
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</table>

### TABLE II

**Voluntary Lateral Movement**

<table>
<thead>
<tr>
<th>From Forced Medial Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscles</td>
</tr>
<tr>
<td>Biceps Femoris</td>
</tr>
<tr>
<td>Semimembranosus-</td>
</tr>
<tr>
<td>semitendinosus</td>
</tr>
<tr>
<td>Gracilis</td>
</tr>
<tr>
<td>Sartorius</td>
</tr>
<tr>
<td>Tensor Fascia Lata</td>
</tr>
<tr>
<td>Popliteus</td>
</tr>
</tbody>
</table>
## TABLE III

**Voluntary Medial Movements**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Biceps Femoris</td>
<td>Mild activity</td>
<td>Moderate activity</td>
</tr>
<tr>
<td>Semimembranosus-semitendinosus</td>
<td>Weak activity</td>
<td>Mild activity</td>
</tr>
<tr>
<td>Gracilis</td>
<td>Very weak activity</td>
<td>Mild activity</td>
</tr>
<tr>
<td>Sartorius</td>
<td>Weak activity</td>
<td>No activity</td>
</tr>
<tr>
<td>Tensor Fascia Lata</td>
<td>No activity</td>
<td>No activity</td>
</tr>
<tr>
<td>Popliteus</td>
<td>Mild activity</td>
<td>Strong activity</td>
</tr>
</tbody>
</table>

## TABLE IV

**Voluntary Medial Movement From Forced Lateral Rotation**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Back to Zero Position from Forced Lat, Rot.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biceps Femoris</td>
<td>Mild activity</td>
</tr>
<tr>
<td>Semimembranosus-semitendinosus</td>
<td>Weak activity</td>
</tr>
<tr>
<td>Gracilis</td>
<td>Weak activity</td>
</tr>
<tr>
<td>Sartorius</td>
<td>Very weak activity</td>
</tr>
<tr>
<td>Tensor Fascia Lata</td>
<td>Very weak activity</td>
</tr>
<tr>
<td>Popliteus</td>
<td>Weak activity</td>
</tr>
</tbody>
</table>
Fig. 2
Fig. 6
Fig. 7
Fig. 9
Fig. 10
Approval Sheet

The thesis submitted by John A. Boczkiewicz has been read and approved by three members of the Department of Anatomy.

The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the thesis is now given final approval with reference to content, form, and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the Degree of Master of Science.

5-25-53

Date

Signature of Adviser