An Electromyographic Investigation of the Activity of the Thigh Muscles During Trunk Flexion and Extension

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AN ELECTROMYOGRAPHIC INVESTIGATION

OF

THE ACTIVITY OF THE THIGH MUSCLES

DURING

TRUNK FLEXION AND EXTENSION

by

Leo Francis Stock

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
LIFE

Leo Francis Stock was born in Washington, District of Columbia, November 18, 1929.

He was graduated from Gonzaga High School, Washington, D.C., June, 1947, and from Georgetown University, June, 1951, with the degree of Bachelor of Science.

He began his graduate studies at Loyola University in September, 1951.
PREFACE

The author wishes to express his thanks to Doctor David S. Jones, who suggested and encouraged the investigation, to Doctor Yvo T. Oester for his many hours of instruction on the science and art of electromyography, to my colleague, John Boczkiewicz, for his untiring cooperation in compiling the data, and finally, to all the students of the medical school who volunteered as subjects for the study.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Previous methods of studying muscle kinesiology--Theoretical basis of electromyography--Advantages and disadvantages of this method--References to other investigators employing this technique--Statement of the problem.</td>
<td></td>
</tr>
<tr>
<td>II. MATERIAL AND METHODS</td>
<td>8</td>
</tr>
<tr>
<td>Muscle screening--The muscles investigated--Method of measuring movement in degrees--Electrode placement.</td>
<td></td>
</tr>
<tr>
<td>III. EXPERIMENTAL RESULTS</td>
<td>13</td>
</tr>
<tr>
<td>The muscles found to be electrically active--Correlation of activity with degrees flexion and extension--Effects of the vertebral brace--The pelvic &quot;marker&quot; brace.</td>
<td></td>
</tr>
<tr>
<td>IV. DISCUSSION</td>
<td>18</td>
</tr>
<tr>
<td>The role of the Hamstrings and rectus femoris as pelvic &quot;stabilizers&quot;--Significance of this function--Possible synergistic function of these muscles--Discussion of gluteal records--Questions raised by periods of electrical silence--Evaluation of vertebral brace--Quantitative differences discussed.</td>
<td></td>
</tr>
<tr>
<td>V. SUMMARY</td>
<td>25</td>
</tr>
<tr>
<td>VI. BIBLIOGRAPHY</td>
<td>27</td>
</tr>
<tr>
<td>VII. FIGURES</td>
<td>29</td>
</tr>
</tbody>
</table>
CHAPTER I

INTRODUCTION

As progress along all frontiers of knowledge daily unfolds, so the scientific investigator in science is ever being presented with new techniques, new instruments, to aid him in his investigations. Yesterday's atomic research is mirrored by today's radioactive tracer techniques in diagnosis and even actual radiation therapy. In the chemical Laboratory, the discovery of new elements has resulted in the synthesis of hitherto unknown alloys which living tissues can tolerate to a marked degree. Thus the plastic surgeon has seen new vistas open before him. The electrocardiograph, the cathode ray oscilloscope, the electron microscope, protein chromatography, but to mention a few, all represent instruments and techniques developed in diversified fields of science but which nevertheless have found a valuable niche in the medical research worker's armamentarium. And when a new technique or more discerning instrument is placed at the disposal of the investigator, concepts and theories must evolve on the basis of the more reliable data the new tool provides. Older theories must stand the test of the new findings. Previous tenets may be reaffirmed, or else be shown untenable. Then again, the new data, due to difficulty of interpretation, may contribute nothing to the
resolution of the problem. But at any rate, a new, more accurate instrument, once established as applicable to a particular investigation, reopens the whole problem to further study and evaluation.

Such a relationship exists between the electromyograph and the study of muscle kinesiology. Kinesiology is the study of movement, and more specifically, the study of the actions of certain muscles during a movement. Before the advent of the electromyograph, muscle kinesiology had been studied by methods which can be classified in three categories. First, there was the analysis of muscles and joints on a purely mechanical basis. This consisted in shortening a given muscle in the cadaver and observing the ensuing motion. This manner of investigation was carried to a high level by Fick (1). Secondly, and more physiological than the previous anatomical method was the one devised by Duchene (2). This technique consisted of electrical stimulation of muscles in vivo and observing the motor effect. Third and lastly, was the method of direct observation and palpation. Since a muscle hardens and changes its shape during contraction, this morphologic change can be detected by palpation. This method of direct observation and palpation was quite successful in the hands of Beevor (3) and Wright (4).

Each of the above methods however, are not without drawbacks when applied to the study of muscle kinesiology.
Because a particular muscle, upon extrinsic manipulation, produces a definite movement in the cadaver, we have no guarantee that such an effect obtains in vivo. Again, the same objection may be raised to electrical stimulation studies of kinesiology. Muscular activity evoked by electrical stimuli and the activity of the same muscle in a volitional integrated performance, are certainly not identical. The third method, that of direct observation, was fundamentally a method of deduction. If, for instance, a movement includes flexion and then extension, in that order, it is logical to assume that first the flexors and then the extensors, will contract. This method, which was based on observations and speculation, rather than experimental facts, had its obvious limitations. Palpation, though more accurate than observation, is seriously limited in kinesiology studies because it is very difficult to palpate several muscles or muscle groups of a limb in motion and determine accurately the time and extent of their contraction. Thus, from the above abbreviated survey of previously employed techniques, we may conclude that none of these gives a clearly defined picture of muscle kinesiology under functional, physiological conditions. A suitable technique should provide accurate data from all the muscles participating in a given movement. The movement under study should be performed under functional, physiological conditions, and should be unencumbered by limitations imposed by experimental apparatus. Finally, the data obtained should give
the temporal sequence of the different muscles involved as they come into action, as well as a relative indication of the amount of work each muscle is contributing to the action. Fulfilling these conditions for analyzing muscle kinesiology, is the method of electromyography.

Electromyography is based on the fact that changes in electrical potential immediately precede motor unit activity. If two metal electrodes are applied to the skin over a muscle or if needle electrodes be inserted directly into the muscle, they pick up potentials of all the motor units within recording range. These potential changes are then amplified and recorded by various devices. Frequently the action potentials are projected on the cathode ray oscilloscope. Here they may be visualized and permanent photographic records made. Other electromyographs are equipped with ink recorders, which furnish a written tracing of the electrical activity of the muscle or muscles under observation. Still another means of making permanent records is the utilization of the tape recorder. In this case, the sounds associated with the contraction of the muscle are recorded. Action potentials can be readily recognized in this manner due to their characteristic crackling noise. In addition, the tape may be re-played into an oscilloscope, whereby the sounds become transferred to the screen as typical action potential contours. Indeed, the only commercial electromyographs on the market at present are equipped with both the
cathode ray oscilloscope and the tape recorder.

The unique value of the electromyograph in kinesiological studies is based on the following findings (5):

1. As mentioned previously, muscular contraction is always preceded by action potentials, and there is no contraction without action potentials. 2. Since for all practical purposes the action potentials start and cease with muscular contraction, this method permits an accurate timing of muscular contractions.

3. The total amplitude of the deflections in one experiment is related to the strength of muscular contractions. 4. If the recording is done with a multi-channel oscillograph, simultaneous recording of several muscle groups can be obtained.

5. Since the skin electrodes consist of small metal discs which may be connected to the recording machine by long, thin wires, the method permits full freedom of action in the execution of the desired motion. 6. The kinesiological record obtained by the electromyographic method gives an immediate picture of muscular activity and also serves as a permanent and objective record for comparison with later studies.

At this point, before proceeding further, it may be well to observe that electromyography is not without its short-comings also. Many times electromyographic data is complex, and difficult to interpret accurately. An excellent discussion of the problems of the interpretation of the electromyogram has been given by Adrian (6) and by Denny-Brown (7). Speci-
Finally, two disadvantages may be cited. First, the skin electrodes record the activity of superficial muscles or rather of the superficial portion of these muscles only. However, the use of needle electrodes can greatly obviate this objection. Furthermore, it has been found that if a motion requires contraction of a certain number of muscle fibers, normally other fibers in this muscle with similar function as well as synergistic muscles contract at the same time. The second objection that may be raised is that the relationship between strength of contraction and amplitude of the tracing is only approximate and can be used only for the same set of electrodes applied to the same site. If the electrodes are applied to different areas, other factors than strength of contraction may influence the amplitude and thus prevent the tracings from being comparable (5). But neither of these objections materially detract from the overall value of the electromyograph in studying muscle kinesiology, at least from a qualitative viewpoint.

Paradoxically, despite its utility, the use of the electromyograph in kinesiological studies is a relatively new departure. Historically, electromyography dates back some twenty-five years. Such workers as Wachholder (1923), Adrian (1929) and Denny-Brown and Pennybaker (1938), all utilized the technique of studying action potentials, both in nerve and skeletal muscle. But these studies were of a fundamental nature, investigating the basic electrical phenomena associated
with neuro-muscular physiology. It has only been within the last five years that reports of electromyographic studies of muscle kinesiology have appeared in the literature. To cite a few examples, in 1960 Sullivan, Mortensen, Miles and Greene of the University of Wisconsin reported on electromyographic studies of m. biceps brachii during normal voluntary movement at the elbow (8). In 1951, Wheatley, and Jahnke of the University of Iowa published a paper on an electromyographic study of the superficial thigh and hip muscles in normal individuals (9). In 1952 Hirschberg and Dacso utilized the electromyograph in the study of clinical kinesiology of the upper extremity (5). Other investigators who have used this method are Inman, Saunders and Abbot (10) studying muscles of the shoulder, Bierman and Yamshon (11, a-b-c) recording from the trapezius, biceps brachii and deltoid; Floyd and Silver (12) on the anterior abdominal wall muscles, and Feinstein, Webb, Inmann and Ralston (13) on the muscle groups of the lower extremity in a phasic action study during various walking activities.

This paper is concerned with an electromyographic study of the thigh muscles stabilizing the pelvis on the femur during flexion and extension of the trunk.
CHAPTER II

Material and Methods

The fifteen subjects used in this investigation were all young male adults, ranging in age from twenty to twenty-three years. All were of normal weight relative to stature. No obese subjects were included.

The investigation was conducted in three parts.

The first phase of the study consisted in an electromyographic screening of all the superficial muscles having attachments on both the pelvis and the femur. A standard six-channel, ink recording electroencephalograph was used for this work. Skin electrodes (metal discs of 0.8 cm. diameter) were applied with electrode jelly and adhesive tape over the muscle to be studied. Since the electroencephalograph is adapted for bipolar leads, each muscle required two electrodes. The distance between any two electrodes of a given set was always four centimeters.

The subjects were instructed to stand erect with heels six inches apart, their hands resting on their "hips". They were then given the signal to flex the trunk slowly forward (without knee flexion) until the limit of trunk flexion was reached. At that point, they would reverse direction and return to the erect position. Once the erect standing position was again attained, the subject would begin trunk extension, proceeding until he could extend no farther without losing
equilibrium. At that point, he would return to the original erect standing position. During both components of this motion, that is both the flexion and the extension, recordings were taken of the following muscles: gluteus maximus; gluteus medius; tensor fascia lata; sartorius; gracilis; rectus femoris; adductor longus; biceps femoris; semimembranosus and semitendinosus. Because the anatomical relation of these latter two muscles (semimembranosus and semitendinosus) makes a division of the electrical activity unfeasible, especially when surface electrodes are used, they were not distinguished from one another in our recordings.

The second phase of the investigation was a more extensive study of the muscles found active in the above mentioned screening procedure. Specifically, it consisted of an electromyographic study of the biceps femoris, semitendinosus-membranosus group, and the rectus femoris, during trunk flexion and extension.

The instrument used in this case was a Sanborn PolyViso four channel electrocardiograph. The augmented unipolar standard limb leads were used. Voltage calibration was $1 \text{ mv} = 1 \text{ cm}$ vertical deflection and the rate-time relation was $1 \text{ sec} = 25 \text{ mm}$.

The subjects were instructed to flex and extend the trunk as described for the first part of the study. An attempt was made to measure these actions in terms of angular degrees.
To accomplish this, the subject would stand next to a wall on which was placed a large protractor. The central reference point of the protractor was put on a level with an estimated transverse axis through the subject's femoral heads. This transverse axis was also perpendicular to the protractor. The erect, standing position was considered as the "zero position". With reference to the zero position, degrees of flexion were designated as "positive" and degrees of extension were considered "negative". Measurements were read as the anterior thoracic wall of the subject passed the degrees marked on the protractor. It was found that the area between the inferior margin of the pectoralis major and the subcostal angle afforded a convenient reference point on the subject. Thus the subject stood interposed between the observer and the protractor. As the subject flexed or extended, the observer would call aloud, at five degree increments, the progress of the subject in terms of angular excursion. The electromyograph operator, in turn, would record the appropriate degree on the tracing. In this manner muscle activity was recorded with reference to degree of trunk movement.

In order to obtain a more accurate delineation of movement at the hip joint a brace (Fig. 1) was devised to minimize the vertebral components of flexion and extension. The brace was securely applied to the back of the subject while he stood in the erect position. One end was strapped over the shoulder and under the axilla, while the other end was secured
below the waist, just under the anterior superior iliac spines. In this way, it was hoped to immobilize the thoracic and lumbar vertebrae during trunk flexion and extension. Each of the fifteen subjects was recorded both with and without the brace.

The surface electrodes used in this part of the work were metal plates, three-fourths inch wide and one inch in length. They were affixed to the skin over the muscle by electrode jelly and rubber straps. The sites of placement were as follows: 1. Rectus femoris. On this muscle, the electrode was placed one-half way between the anterior superior iliac spine and the tibial tuberosity. 2. Hamstrings. In the case of these muscles, the tendons of insertion were palpated lateral and medial to the popliteal fossa. Tracing the tendons superiorly, the electrodes were placed at that point where the tendons merged with the fleshy bellies of the muscles. In the case of the medial Hamstrings, the tendon of the semitendinosus served as the guide for electrode placement.

The third part of the investigation involved an experimental procedure similar to the regime described for the second part, and differed from it only in that a Meditron electromyograph and needle electrodes were used. The sites of electrode needle insertion were the same as the surface placement pattern outlined in part two of the procedure.

Finally, as an adjunct to the three phases of electromyographic investigation, one additional study was conducted to
observe pelvic motion directly. In order to determine exactly when the pelvis began to participate in trunk flexion and extension, a pelvic "marker" brace was devised. (Fig. 2). This consisted of two wooden arms assembled in the form of a "V". The vertex of the "V" was designed to rest on the symphysis pubis, while each limb of the brace rested on one of the anterior superior iliac spines. When the brace was secured by straps on the subject, a pointer lever, projecting anteriorly from the brace, would register any pelvic movement in the sagittal plane.
CHAPTER III
Experimental Results

The first phase of the study, namely the electromyographic screening of the superficial thigh muscles showing activity during flexion and extension of the trunk, indicated the following muscles were active: the biceps femoris, the semimembranosus - tendinosus group, the rectus femoris, and the gluteus maximus. However, the gluteus exhibited activity in only two of twelve subjects used to record from this muscle. The biceps femoris, the semimembranosus - tendinosus group, and the rectus femoris showed activity in all fifteen subjects investigated.

More specifically, it was found that the biceps femoris and the semimembranosus - tendinosus group demonstrated action potentials only during the trunk flexion and trunk erection phases of the subject's movements. That is to say, these muscles showed electrical activity during flexion forward from the erect position, and then, once the subject had attained the maximum forward excursion of trunk flexion, these same muscles would continue to show activity while the subject returned to the erect position. These muscles were electrically silent during trunk extension and the subsequent return from extension to the erect position.

In the two cases where activity was recorded from the
gluteus maximus, it was found that this muscle demonstrated
electrical activity during the same actions (previously des-
cribed) in which the hamstrings showed activity. Like the
hamstrings, this muscle also was silent during trunk extension
movements.

The rectus femoris was electrically silent during
trunk flexion actions. But it did exhibit electrical activity
during extension, and also during the return of the subject
from extension to the erect position.

Recordings made with the vertebral brace did not
differ qualitatively from these records taken without it. The
same muscles were electrically active in both cases.

Comparing the initiation of muscle activity with the
degrees of flexion or extension attained, the following obser-
vations were made. First, let us consider the hamstrings. The
semimembranosus - tendinosus group and the biceps femoris both
began to exhibit electrical activity simultaneously (Fig. 3).
Recording without the vertebral brace, this activity began at
approximately fifteen degrees flexion (Figs. 4, 5). It contin-
ued, progressively increasing until the subject attained his
maximum flexion. This was found to be approximately eighty-
seven degrees. At this point, when the subject would reverse
his flexion and begin to return to the erect standing position,
the greatest electrical activity was recorded from these
muscles (Figs. 6, 7). This activity would then slowly decrease
as the subject returned to the erect position, and finally action potentials would cease to be recorded at about ten degrees flexion. Cessation of activity was simultaneous in both the biceps femoris and the semimembranosus - tendinosus group (Fig. 8). However, during the periods in which the hamstrings did exhibit electrical activity, the semimembranosus - tendinosus group appeared to be more active than the biceps femoris. This observation is based on the comparison of the frequency and amplitude of action potentials recorded from these muscles.

Those recordings, indicating hamstring activity beginning at fifteen degrees flexion, were made on subjects standing in their stocking feet. The range of values for fifteen subjects was from thirteen degrees to seventeen degrees, with a mean of fifteen degrees. Interestingly enough, recordings taken from ten subjects standing with their shoes on, gave a range of values from five degrees to twenty degrees, with a mean tending to be less than ten degrees.

In the two instances of activity recorded from the gluteus maximus, potential changes began and ceased simultaneously with those of the hamstrings. Gluteal activity, based on the frequency and number of action potentials obtained, was greater than either that of the semimembranosus - tendinosus group, or that of the biceps femoris.

Recordings using the vertebral brace showed several modifications with regard to flexion movements. Hamstring activity began at eight degrees flexion when the brace was on
the subject. The average maximum flexion was now sixty degrees, with maximum hamstring activity again being exhibited just as the subject began his return to the erect position. In the case of records made with the brace however, cessation of activity was not until three degrees flexion had been passed and the subject practically in the erect position once more.

The rectus femoris showed electrical activity that commenced at approximately seventeen degrees extension (Fig. 9). This activity gradually increased until the limit of extension (sixty degrees) was attained. At this point, when the subject started to return to the erect position, maximum activity was recorded (Fig. 10). This activity gradually diminished until the subject reached sixteen degrees extension, at which point cessation of electrical activity was noted (Fig. 11).

The use of the vertebral brace limited extension to approximately twenty-five degrees. Corresponding to this limitation, the period of greatest activity in the rectus femoris was now recorded just as the subject started to right himself, having attained the twenty-five degree extension limit imposed by the brace. However, the use of the brace did not modify the points of origin and cessation of this muscle's electrical activity. These remained seventeen and sixteen degrees respectively, the same as without the brace.

Lastly, we may turn our attention to the results obtained in the studies with the pelvic "marker" brace. The
reader will recall this device was employed to observe directly the pelvis during flexion and extension. During flexion, the pelvis "marker" device began to move at sixty-five degrees. It continued to indicate pelvic motion until the individual had attained his maximum flexion (eighty-seven degrees). In the course of extension, the indicator was observed to move from eight to ten degrees. However, no further excursion of the pointer was observed from ten degrees to the average maximum extension (sixty degrees).
CHAPTER IV

Discussion of Results

The concept of the hamstrings and the rectus femoris stabilizing the pelvis during trunk flexion and extension certainly puts no undue strain on the imagination. These muscles, attached "fore and aft" on the pelvis so to speak, are ideally situated for such a function. In discussing such a function though, we must keep in mind that movements of trunk flexion and extension are not accomplished by a simple flexion-extension action of the hip joint, but rather are accompanied by at least two separate pelvic components, in addition to the main vertebral component. The first of these to come into play during trunk flexion or extension, is an antero-postero shift of the pelvis in the horizontal plane. (Figs. 12, 13). The direction of the pelvic shift is opposite the direction of trunk movement. Thus during trunk flexion, the pelvis moves posteriorly in the horizontal plane, while in extension the shift is anterior. (Figs. 12, 13). However, the spatial relations of the pelvis per se do not change during this phase of the action. That is to say, the plane of the pelvic inlet does not vary, but retains the same position as when the trunk was erect.

The second component of pelvic motion in the actions studied, was that of actual hip flexion or extension. We are now dealing with pelvic flexion or extension as such. In the
course of trunk flexion, pelvic flexion did not become manifest until sixty-five degrees trunk excursion were attained. From this, we concluded that sixty-five degrees represents the usual vertebral component. Further excursion, from sixty-five to eighty-seven degrees represents true pelvic flexion. With regard to trunk extension, our observations would indicate that the pelvic component is very slight, amounting to only eight degrees. We feel this limitation is imposed primarily by the ilio-femoral ligament, which produces a stout and formidable check on any backward tilt of the pelvis.

Let us now attempt to correlate the above considerations with the electromyographic findings. If we consider flexion as an example, we can postulate that as movement proceeds, increasing toward the maximum, more and more stretch is exerted on the hamstrings. This tension arises from two sources. First, as the pelvis shifts posteriorly in the horizontal plane, the distance between the origin and the insertion of the hamstrings becomes gradually greater. (Fig. 12). This in turn stretches these muscles. Secondly, when sixty-five degrees flexion are attained, and the already shifted pelvis now begins to flex on the thigh, further tension is exerted on the hamstrings. The increasing stretch exerts a tension on the proprioceptive receptors associated with the intrafusal muscle fibers of the hamstrings, and these muscles reflexly contract to oppose the stretch. As the stretch becomes greater, so does the muscular
contraction opposing it. This increased muscular activity is mirrored by an increase in the frequency and amplitude of the action potentials recorded from the muscle. And in effect, the results of this investigation support this hypothesis. As the angle of flexion becomes greater, so does the electrical activity of the hamstrings. The same relation holds true for the rectus femoris during extension, but in this case the tension on the muscle results predominately from the anterior pelvic shift. Thus it is possible to visualize these muscles as dynamic "guy" ropes, stabilizing the pelvis and modulating pelvic motion, either anteriorly or posteriorly.

With regard to the action potentials displayed by the rectus femoris, it may be well to mention another possible source of this activity. During the course of trunk extension, one usually flexes the knee joints slightly as an aid to maintaining equilibrium. Consequent to knee flexion under these circumstances, we would anticipate the rectus femoris to be stretched, and thus demonstrate electrical activity after the manner previously postulated for the hamstrings. To eliminate this extraneous source of activity, all subjects were particularly cautioned concerning the necessity of maintaining the knee joints extended. Nevertheless, it is possible that some imperceptible flexion did obtain, and in some cases this may explain a portion of the activity demonstrated by the rectus femoris.
Other experimental results impute further importance to the pelvic stabilizing function of the hamstrings and rectus femoris. Our pelvic "marker" studies indicate at least sixty-five degrees of the average eighty-seven degrees of trunk flexion are attained by the summation of vertebral components. On the basis of the same studies, the vertebral component of extension is even more pronounced. It accounts for as much as fifty degrees of an expected sixty degree extension. (The pointer of the pelvic brace did not move beyond ten degrees extension, yet sixty degrees of extension can usually be attained.) Thus it would appear that most of trunk flexion and extension occurs at the intervertebral joints. It therefore follows that much of the movement of flexion and extension must be effected by the anterior abdominal musculature in the one case, and the erector spinae mass in the other case. But both of these muscle groups attach to the pelvis. The efficiency of these muscles in accomplishing flexion and extension then, would depend to no small extent on the relative stability of the pelvis, which is now serving as the origin of these muscles. Considered in this manner, the role of the hamstrings and the rectus femoris as "pelvic stabilizers" assumes an added significance.

Another possible function of the hamstrings is a synergistic activity in the return to the erect position after flexion. This could be an explanation for recording maximal
electrical activity immediately upon initiation of the recovery movement back to the erect position. The same explanation could also be applied to the rectus femoris and the observation of maximal electrical activity immediately upon initiation of the recovery movement after maximal extension.

Perhaps one of the most unexpected results of the investigation was the comparative lack of electrical activity from the gluteus maximus muscle. A priori, one might expect this large, powerful extensor of the thigh to be of prime importance in stabilizing the pelvis during the flexion phases of the movements studied. However, this function of the muscle was certainly not observed consistently. Action potentials were observed from this muscle in only two of twelve subjects.

One reason for this relative lack of activity could be the bulk of the muscle itself. A large, massive muscle, adapted to powerful movements, we might not expect the gluteus to be as sensitive to proprioceptive stretch stimuli as say, the hamstrings. Nor might we expect the gluteus to exhibit the same discretely graduated contraction as manifested by the hamstrings. Instead, the muscle appears to discharge suddenly and massively when the maintenance of the equilibrium of the flexing subject requires it to do so. Indeed, one receives the impression that the gluteus serves as a reserve source of stabilizing power, which may be mobilized if the postural balance of the individual warrants it.
The periods of electrical silence, during both flexion and extension, pose several questions. What do the iso-electric segments from zero to fifteen degrees flexion, and from zero to seventeen degrees extension, indicate? Could it be that the pelvis adapts its ball and socket relationship with the femoral heads in such a manner that no muscular stabilization is required during these periods of electrical silence? Or do other muscles, which were not considered in this investigation, act to stabilize the pelvis during the actions described? Unfortunately, the results of this present investigation do not resolve either of these questions. We can only reiterate that a period of electrical silence was observed in the hamstrings during extension from zero to fifteen degrees, and in the rectus femoris, during extension from zero to seventeen degrees. This is all within the movement in which the pelvis is shifting anteriorly or posteriorly but not tipping. Perhaps the shifting of the pelvis to preserve the center of balance does not alter the stability of the hip joints until several degrees of flexion have been attained.

The use of the vertebral brace, with the intent of immobilizing the thoracic and lumbar vertebrae during the performance of the movements studied, was generally ineffective. The brace did limit vertebral motion to a variable degree, especially in extension movements, but the limitation was not sufficiently complete. For example, average maximum flexion
with the brace was sixty degrees. Observations made directly on the pelvis, with the pelvic "marker" brace, indicated the pelvis did not move until sixty-five degrees flexion were attained. Using both the vertebral brace and the pelvic brace together, it was found that the pelvis began to move at forty-five degrees flexion. Thus we see that twenty degrees limitation was accomplished by means of the vertebral brace, but we also note it still allowed forty-five degrees of vertebral flexion to take place.

The fact that the semimembranosus-tendinosus group exhibited more electrical activity than the biceps femoris during an action in which both were active simultaneously, is perhaps deserving of comment. Unipolar surface electrodes were used in this study. The unipolar electrode records the sum of all the electrical activity occurring opposite it. The electrode recording activity from the semimembranosus-tendinosus group very likely reflected contributions from both muscles. But the electrode used over the biceps femoris was probably recording from this one muscle only. Therefore, we would expect that a comparison of the records of these two muscle groups would indicate more activity where we have two active muscles, than where we have only one.
CHAPTER V

Summary

1. Electromyographic records were taken from the superficial thigh muscles to determine their role, if any, in stabilizing the pelvis during flexion and extension. The muscles recorded from were as follows: gluteus maximus, tensor fascia lata, sartorius, gracilis, rectus femoris, adductor longus, semimembranosus-tendinosus group, and the biceps femoris.

2. The semimembranosus-tendinosus group, and the biceps femoris were electrically active during flexion. In two of twelve subjects, the gluteus maximus exhibited activity.

3. The rectus femoris was electrically active during trunk extension.

4. Muscle activity was correlated with degrees of flexion and extension. Electrical silence was observed from zero to fifteen degrees flexion, and from zero to seventeen degrees extension.

5. Trunk flexion and extension were analyzed in terms of both intervertebral joint and hip joint components. The hip joint does not appear to contribute to flexion until sixty-five degrees have been attained through vertebral flexion. At least fifty degrees of an average sixty degree trunk extension were also found to be due to vertebral extension, with the hip joint remaining inactive in this movement after
the first ten degrees extension were attained.
CHAPTER VI

Bibliography


CHAPTER VII

Figures
FIGURE 1

THE VERTEBRAL BRACE

Physics
Stritch School of Medicine
Loyola University
FIGURE 2
THE PELVIC MARKER BRACE

Note flexible pointer to the left. This is bent perpendicular to the sagittal plane when the brace is in place.
Note the simultaneous activity in each of the hamstrings.
FIGURE 8

Biceps Femoris

Semimembranosus - Tendinosus

Note simultaneous cessation of activity in both tracings.
Note cessation of activity at approximately sixteen degrees.
FIGURE 12
DIAGRAM ILLUSTRATING PELVIC SHIFT DURING TRUNK FLEXION
FIGURE 13
DIAGRAM ILLUSTRATING PELVIC SHIFT DURING TRUNK EXTENSION

Hamstrings

Rectus Femoris
APPROVAL SHEET

The thesis submitted by Leo F. Stock 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.

S. S. Jones
Signature of Adviser

Date: 5-25-53