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Electromyography of the Back Muscles During Respiration and Speech

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ELECTROMYOGRAPHY OF THE BACK MUSCLES

DURING RESPIRATION AND SPEECH

by

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LIFE

Albert Avery Halls was born in Danville, Illinois, January 4, 1928.

He was graduated from Hammond High School, Hammond, Indiana, in June, 1946, and from the University of Chicago, in June, 1957, with the degree of Bachelor of Science.

He began his graduate studies at Loyola University in September, 1957.

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I am very appreciative of those who gave generously of their time so that this investigation might be carried out.

To my many friends, I am indebted for the help and encouragement they have given me in this investigation and I take this opportunity of expressing to them my very grateful thanks.

Lastly, to my wife I wish to express my deepest appreciation for the encouragement, assistance and typing of this thesis. Without her help the investigation would have been more arduous and long delayed.

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CHAPTER I

INTRODUCTION

A. Introductory remarks and statement of the problem.

This investigation was undertaken to determine whether the intrinsic musculature of the back--erector spinae muscles-has any role in normal respiration and/or phonotion. One can observe that in eupnea, physiologic respiration, the sternum rises and falls. The vertebral column is extended and flexed during inspiration and expiration respectively. As one speaks the back muscles can be felt to contract.

The intrinsic back muscles are those groups of muscles derived from the epimeres of the myotomes and extend from the occiput, caudally to the pelvis, and laterally to the posterior angles of the ribs. The back muscles can, for purpose of study, be subdivided into the categories of depths, levels, and columns. The columns are the median, medial, and lateral. The levels would be the cervical, thoracic and lumbar and the depths are the superficial, intermediate, and deep. The superficial three columns and the two levels, thoracic and lumbar, are being investigated in present study. (See Appendix III for details of these muscles.)

Respiration consists of two distinct acts, inspiration

and expiration, in which the air successively enters the lungs and is expelled from them by alternate increase and diminution of the thoracic cavity. Thane (1899) states that the movements of the thoracic walls are four:

1) "The anterior-posterior diameter is increased by a forward movement of the sternum with the attached ribs and cartilages.
2) The vertical diameter of the thoracic cavity is increased by the descent of the diaphragm which forms its floor and the lower ribs are drawn backwards and outwards rather than raised.
3) The transverse diameter of the thoracic cavity is increased by the elevation and eversion of the ribs.
4) The extension of the vertebral column is an important factor. When the column is bent forward the ribs are approximated in the concavity of the curve and when the column is extended the ribs are separated."

The method selected for this study is electromyography because of its reproducibility and the functional principle upon which it is based: The contraction of any muscle is accompanied by action potentials which can be picked up and transmitted to a suitable recording device (the electromyograph) where the potentials are amplified and recorded on

paper (See Licht for history and details.

B. Review of the literature

The pair of erector spinae muscles have been treated by previous investigators as a unit rather than investigation of the individual components of the muscle in relation to the entire muscle. The literature is scanty, widely scattered and very indefinite for the most part. Further, the investigators in general do not state what technique was used to investigating these muscles, how many subjects were used, or on what mechanical basis the statements are made. In short, to date the back muscles have not been investigated in a thorough fashion.

The erector spinae muscles were studied by Duchenne in 1867 who stimulated these muscles with electrical current. When the electrodes were placed over the site of the common aponeurosis of origin the trunk moved obliquely backward and toward the side of stimulation and the vertebrae "from around the eighth dorsal vertebra" described a curve with the convexity away from the side of stimulation. If the electrodes were placed on the lateral attachments of the longissimus dorsi muscle the same movement resulted as when the sacrolumbar muscles themselves were stimulated. With the electrodes near the spinous processes of the dorsal vertebrae

corresponding, therefore, to the fibers of the spinalis muscles, direct extension of the vertebra was produced. Finally, when the electrodes were over the iliocostalis muscles a powerful lateral inclination of the trunk was effected because, " the fibers are more perpendicular to the levers of the ribs which they move and because these levers are longer."

Thane (1899) described the erector spinae muscles as "indirectly aiding in inspiration if the spine is extended and assisting in expiration if the spinal column is fixated." The costal attachments of the muscles presumably accomplished the latter action. His work is apparently based upon logic and dissection but this is not stated.

Beevor (1904) investigated these muscles by palpating them in the living body while asking the subject to perform some action. The erector spinae muscles can be felt to contract under the following conditions:

1) upon tilting the head forward while standing erect (thus upsetting the equilibrium of the body.)
2) upon abducting the humerus or advancing it while standing erect.

Adams cited by Beevor (1904)(p 41) and Walmsley (1923) (p 174), refers to both of these conditions as "a state of vigilant repose". Apparently what is meant is that the erector spinae

muscles function whenever the equilibrium of the body is threatened.

Walmsley (1923) describes the erector spinae muscles as "indirectly elevating the ribs". His method is also apparently based upon dissection and logic but this is not stated. Grant (1942) in Morris' Human Anatomy edited by Schaeffer, 10th Ed., p 482, states that the lateral superficial column, "iliocostalis lumborum", depresses the ribs while the medial superficial column, "iliocostalis cervicis", elevates them. But no mention is made of the method in which this was determined or what investigator had made this conclusion.

Akerblom (1948) found in twelve subjects there was no electrical activity in eight of the subjects when the spinal column was flexed, i.e. there was no appreciable difference in electromyogram from the resting state. Kelton and Wright (1949) showed in one subject in the "easy standing position" no activity from the erector spinae muscles, while Floyd and Silvers (1955) showed that activity was present during the attitudes of beginning flexion but there was a cessation of the impulses recorded in the electromyogram in complete flexion because the ligaments took over the task of holding the body. Only a low level of discharge was noted in an upright position.

Campbell (1958) has examined the erector spinae muscles

(iliocostalis,longissimus and semispinalis) with needle and surface electrodes and concluded that these muscles are active during expiration.

C. TABULATION OF PREVIOUS INVESTIGATORS

	1867 Duchenne	1899 Thane	1904 Beevor	1923 Walmsley	1942 Grant	1948 Akerblom (12 sub.)	1949 Kelton & Wright (only 1 sub. used)	1955 Floyd & Silvers ("Most" sub. of 150 used)	1958 Campbell	Summary
Ilio-costalis	Lateral flexion Trunk obliquely moved backward toward side of stimulation	Expiration costal attachment if spinal column is fixated	* Contracts whenever equilibrium is disturbed	Elevators of ribs	Depresses ribs and elevates them (Ilio-cervices)	No activity in complete flexion (8 sub.)	* No electrical activity	* No electrical activity or low level of activity in complete flexion or erect standing position	Inspiration and expiration	Inspiration and expiration. No activity recorded in complete flexion
Long-issimus	Trunk moved obliquely backward toward side of stimulation								Inspiration	Inspiration
Semi-spinalis	Extension of vertebra								Extension of the spine and inspiration	Extension of the spine and inspiration

* No specific component of the erector spinae muscles stated. Results are for the erector spinae muscles as a whole.

Blank spaces indicate items not studied in each case. The above tabulation was drawn relatively to the conclusions of previous investigators. (Refer to text; pp 3-6)

CHAPTER II

PROCEDURE

Materials

The Grass Model III D electroencephalograph was employed in recording action potentials from the muscles under study. Four channels were used in making simultaneous recordings from four different sites. A fifth channel was used to record the phases of respiration and speech. (Fig. 1)

Each electrode, having a different color cable, was plugged into the appropriate jack on the electrode board which transmitted the potentials into the main panel. Thus, any two electrodes could be channeled into one channel or all channels. The impulses were transmitted from the switch panel into two serial amplifying systems, a preamplifier and an amplifier. From the latter the impulses were then conducted to the ink-writing pens of the console.

The above method of recording was used rather than the ocilloscope since it was shown by Floyd and Silvers (1952) to be practically the same if the frequency of discharge of the muscles were no larger than fifty cycles per second. If the above conditions obtained, the amplitude of the potential remained the same externally.

Surface electrodes supplied by the Grass Instrument Company were used in this study. These electrodes are cup-shaped silver discs, about eight millimeters in diameter. Surface electrodes were used rather than needle electrodes because the object was to study a large mass of muscles and

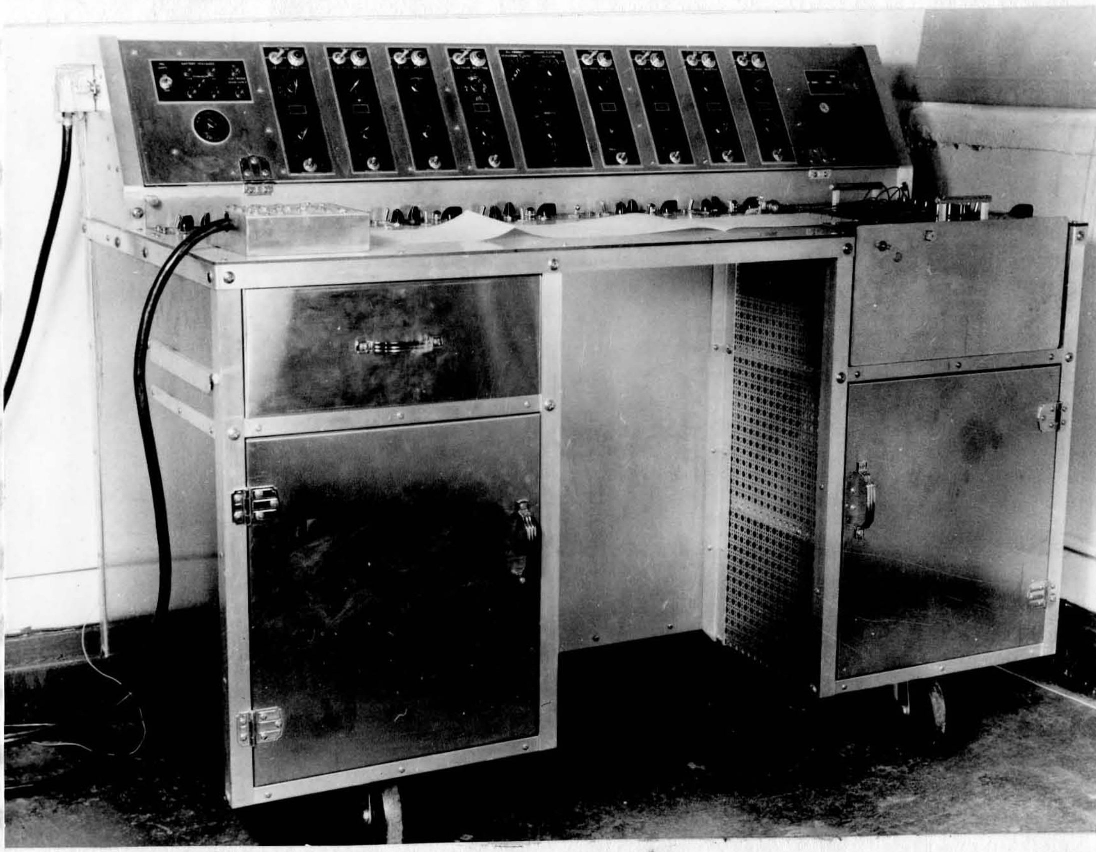

FIGURE I

GRASS MODEL III D ELECTROENCEPHALOGRAPH

needle electrodes are only useful in sampling just a few millimeters around the tip of the needle. (Floyd and Silvers 1955) Needle electrodes also cause pain and were thought to be a hindrance to having the subject relax in certain phases of the study. The disadvantage of using the surface electrodes was that frequently they slipped and had to be replaced after certain maneuvers.

The method used to show the inspiratory phase of respiration was to manually deflect the pen upwards when the subject inhaled or spoke certain words. The pen was deflected downward when the subject exhaled.

A total of ten subjects participated in the collection of this data:four females (nurses), six males (students). All subjects used in this investigation were between the ages of twenty and thirty years.

Methods

1. Initially the subjects were to be divided into groups of erect posture, partial flexion, and complete flexion, and these various groups contrasted with each other. This idea was abandoned since prerecording showed that each subject should repeat the entire set of maneuvers to eliminate the variance between individuals which might have taken place.

2. Preliminary testing showed that the greatest number of action potentials could be expected during the expiratory phase of respiration and that muscle potentials for speech were beyond the sensitivity of the apparatus.

3. The muscles that were to be studied were the iliocostalis and the longissimus muscles. The location of these muscles was first ascertained on cadavers by dissection. The topography of the muscle was carefully outlined on the skin and anatomical fixed landmarks were sought in order to identify the muscles later in the living subjects. The motor point which was seen to be in the middle of the muscle belly, was found to be midway between the middle of the crest of the ilium and the last rib. The longissimus muscle was approximately a hand's breadth from the vertebral column. Also at dissection the serratus posterior inferior muscle was seen to cover portions of the iliocostalis muscle but the site selected for electrode study would be covered only by lumbodorsal fascia. Also Floyd and Silvers (1955) have shown that action potentials were not picked up from surrounding muscles when examined by needle electrodes during their study. They examined the following muscles: serratus posterior inferior, latissimus dorsi, trapezius, psoas, abdominal muscles, quadratus lumborum, and glutei.

4. Accordingly, the elecrodes were placed as outlined above on the muscle under study, either the right or left iliocostalis and longissimus muscle.

The transverse line for the electrodes was determined by measuring the total transverse thickness of the erector spinae muscle and then taking 90% and 10% this distance for the iliocostalis and longissimus muscles respectively. The vertical level was then specifically located by placing the electrode midway between the last rib and the middle of the crest of the ilium for iliocostalis and longissimus muscles.

Another set of electrodes wase placed on the above two muscles one to one half centimeter below the above located electrodes. This placement of the electrodes is approximately at the second and third lumbar levels. (Fig.2)

The skin over these sites was abraded with the electrode paste supplied by the Grass Instrument Company. The electrode was filled with the paste, placed on the site and an one centimeter square of cotton gauze was placed over the electrode. The electrode was then secured to the skin by three strips of cellulose tape.

Numerous other methods were tried in securing the electrodes but the cellulose tape was preferred. Collodion was found not to hold the elctrode while the subject was standing erect.

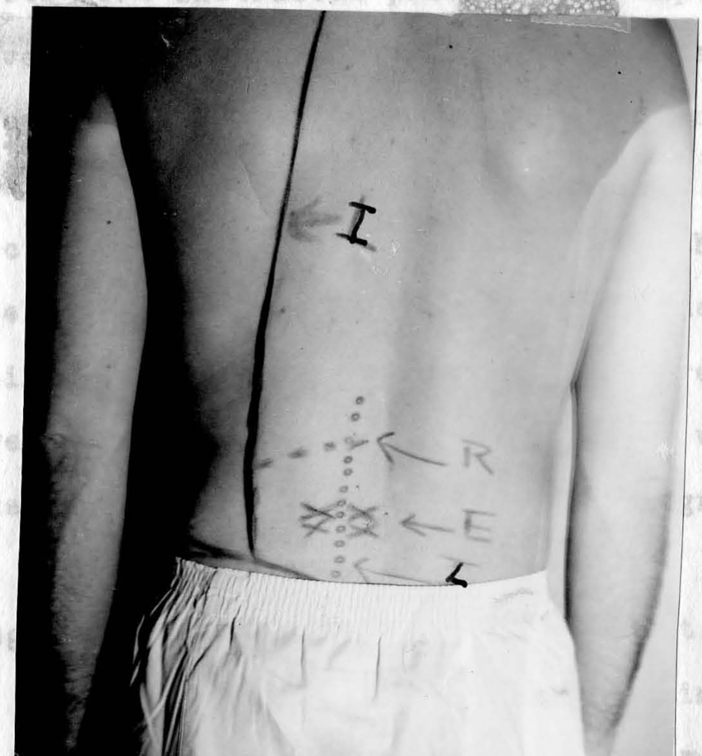

FIGURE 2

PHOTOGRAPH OF THE BACK WITH SITES OF ELECTRODES INDICATED

Code: L, Longissimus muscle

I, Iliocostalis muscle

R, Last rib

E, Electrodes sites

Adhesive tape was less flexible and seemed to slip more easily than the cellulose tape.

5. The subjects were instructed prior to the experiment as to what the investigator desired to know and the mechanism of the recording apparatus. The above was done to place the subject at ease.

The subjects were asked to stand erect with the feet apart so that they felt at ease, and to allow their hands to hang loosely at their sides. The distance the feet were apart varied from twelve to fifteen inches and the feet were usually turned outwards in an approximated fourty-five degree angle. (Fig. 3)

A counting system was devised similar to that used by Pauly (1952). The investigator would begin counting one, two, three.....eight; on the count of four the subject would begin to inhale and simultaneously an upward deflection was made manually on the appropriate writing pen of the console. At the count of eight the subject would begin exhalation and a downward deflection was simultaneously made on the writing pen. The exhalation would continue until the maximum effort had been expended as the investigator could determine by watching the subject. The investigator demonstrated this

procedure and the subject practiced several times before the recordings were taken. The subject was then allowed to rest a few minutes after which the recordings were taken. The experiment was then repeated after a rest period.

The above method of obtaining records of respiration was

FIGURE 3

PHOTOGRAPH OF THE SUBJECT IN THE STANDING POSITION

repeated with the subject in partially flexed and completely flexed positions. (Fig. 4 and 5) Complete flexion was assured by the investigator grasping the shoulders of the subject and gently rocking the subject's body until there was felt to be a complete freedom of motion. The erector spinae muscle was

FIGURE 4

PHOTOGRAPH OF THE SUBJECT IN THE PARTIAL FLEXED POSITION

found previously by Floyd and Silvers (1955) to be electrically silent in this position.

To record speech potentials a nursery rhyme was recited, the words being ennunciated at three second intervals and an upward deflection of the pen was made with the ennunciation of

FIGURE 5

PHOTOGRAPH OF THE SUBJECT IN THE COMPLETE FLEXED POSITION

each word or syllable. The subject was in an erect position when the words were recited.

6. The height of the spike cannot be correlated with the number of motor units firing because this correlation can only be made on isolated muscle fibers that are contracting isometrically. (Campbell 1958) Thus the tracings obtained were given four classifications:

The type 1 tracing shows no disturbance of the base line except the electrocardiogram.

The type 2 tracings show a disturbance of the base line but sporadic and seemily unassociated with the test maneuver.

The type 3 tracings show potentials with moderate or high amplitude definitely associated with the test maneuver.

The type 4 tracings show potentials with low amplitude but associated with the test maneuver. (Fig. 6)

A questionnaire (Appendix I) was used to detect factors which might influence the activity of the muscle under investigation.

The subject's occupation, length of time in a car, exercise status plus any revelant history (e.g. history of injury to back, upper arm or abdomen, recent history of moving heavy objects, ect.) were noted.

This questionnaire was found to be very valuable in dis-

covering history of injuries to the back and the recent heavy physical labor involving the use of the back muscles.

The electromyographic data sheet (Appendix II) was devised so that every record would be complete and have settings of all dials of electroencephalograph on one sheet. The data sheet

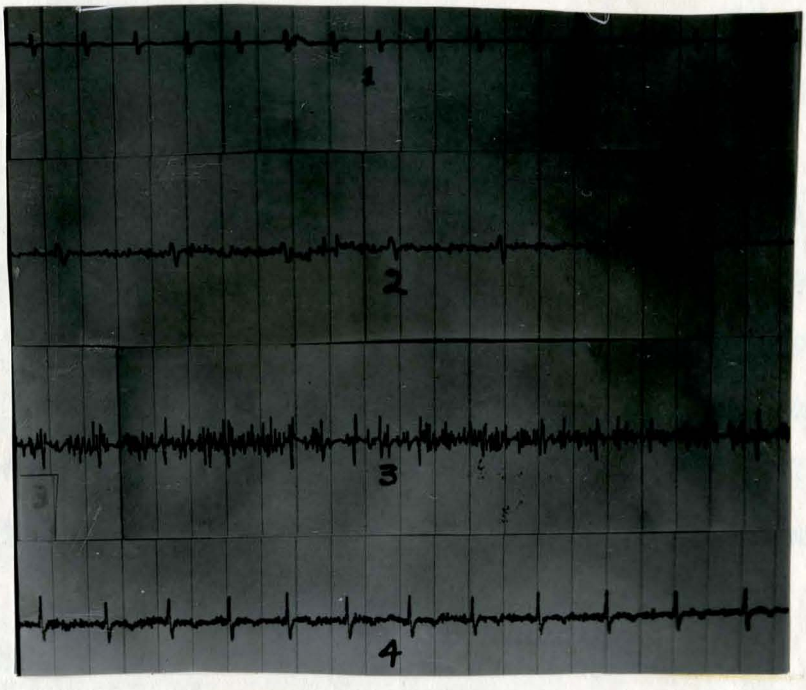

FIGURE 6

TYPES OF TRACINGS

Refer to text p. 18

also helped in maintaining a uniform recording procedure.

The records were examined individually and a summary sheet was made for each subject according to the above scheme. The records were then placed on a master summary sheet to determine if any type of trend could be established regarding speech and respiration.

CHAPTER III

EXPERIMENTAL RESULTS

A. General

The following results are taken from recordings from ten different subjects: six males and four females.

The recordings never show an isoelectric line since they always contain the electrocardiogram complex. This complex serves as a time device and to inform the investigator that the lead is recording satisfactorily.(Campbell 1958)

The tables: summary table of experimental results, records of individuals during respiration in the three postural attitudes (Appendices IV and V) summarize the type of electromyographic tracings obtained during the period of inhalation while the subject was in the erect standing, partially flexed, and completely flexed positions. (For simple tracings see Fig. 6.)

The discussion is according to the position of the subject and then to the particular muscle during both phases of respiration.

B. Records of subjects

Subject one:

P.R. (male) (right side)

1. Erect standing position

a. Inspiration

The iliocostalis muscle shows potentials between inspiration and expiration. These potentials are of reduced amplitude (4) and are associated with inspiration.

The longissimus muscle shows potentials beginning almost as soon as the "inspire" signal is given. The amplitude is small.

b. Expiration

The iliocostalis muscle shows potentials of moderate amplitude (3).

The longissimus muscle shows potentials of large amplitude (3) during expiration.

2. In speaking

The iliocostalis muscle at no time shows potentials during the period the subject spoke the nursery rhyme.

The longissimus muscle shows activity but it cannot be ascertained whether any of the potentials are associated with any particular word or phrase.

3. Partial flexion

a. Inspiration

The iliocostalis muscle shows potentials of moderate amplitude (3).

The longissimus muscle shows potentials of high amplitude (3).

b. Expiration

The iliocostalis muscle shows potentials of moderate amplitude (3).

The longissimus muscle shows potentials of moderate amplitude (3).

4. Complete flexion

a. Inspiration

The iliocostalis muscle shows very small action potentials (4).

The longissimus muscle shows sporadic bursts of activity (2).

b. Expiration

The iliocostalis muscle shows no activity (1). The base line is only disturbed by the electrocardiogram.

The longissimus muscle shows no change in the base line (1).

Subject two:

B.H. (male) (left side)

1. Erect standing position

a. Inspiration

The iliocostalis muscle shows potentials of low amplitude (4).

The longissimus muscle shows potentials of low amplitude (4).

b. Expiration

The iliocostalis and longissimus muscles show potentials of moderate amplitude (3).

2. In speaking

The electromyogram shows potentials which are sporadic and do not seem to be associated with any particular words or phrases of the rhyme.

3. Partial flexion

a. Inspiration

There seemed to be no increase in the number of action potentials in the iliocostalis or longissimus muscles.

b. Expiration

There appears to be no increase in the number of action potentials in the iliocostalis or longissimus muscles. The

background activity is too dense to properly evaluate the recordings.

4. Complete flexion

a. Inspiration

The iliocostalis and longissimus muscles show potentials of large amplitude (3).

b. Expiration

The iliocostalis muscle shows potentials of moderate amplitude (3).

The longissimus muscle shows potentials of small amplitude (4).

Subject three:

B.G. (female) (right side)

Note: Six days before the subject was tested she had done heavy physical labor, as indicated on the questionnaire, i.e. pushing two cars out of the snow. At no time during the recordings was it possible to get electrical silence on this subject.

1. Erect standing position

a. Inspiration

The iliocostalis and longissimus muscles showed potentials with moderate amplitude (3).

b. Expiration

The iliocostalis and longissimus muscles showed action

potentials of low amplitude (4).

Spikes can actually be counted on all three replications.

2. In speaking

The iliocostalis muscle shows potentials of sporadic bursts (2).

The longissimus muscles show potentials throughout the recitation period;however, no correlation can be made with any set of words or phrases.

3. Partial flexion

a. Inspiration

The iliocostalis muscles shows an increase in the number of potentials and also the height. They are of moderate amplitude (3).

The longissimus muscle shows potentials with low amplitude (4).

b. Expiration

The iliocostalis muscle potentials show a decrease in the amplitude (4).

The longissimus muscle shows the amplitude returning almost to the base line but the activity was still thought to be (4).

4. Complete flexion

a. Inspiration

The iliocostalis and longissimus muscles show potentials with low amplitude (4).

b. Expiration

The iliocostalis and longissimus muscles showed no activity (1); the recording was interrupted only by the ever present electrocardiogram complex.

Subject four:

B.S. (male) (right side)

1. Erect standing position

a. Inspiration

The iliocostalis and longissimus muscles showed potentials with very low amplitude (4).

b. Expiration

The iliocostalis and longissimus muscles showed action potentials with very low amplitude (4).

2. In speaking

No potentials could be recorded from either the iliocostalis or longissimus muscles.

3. Partial flexion

a. Inspiration

The iliocostalis muscle shows potentials with large amplitude (3).

The longissimus muscle shows potentials which are sporadic (2).

b. Expiration

The iliocostalis muscle shows potentials of moderate amplitude (3).

The longissimus muscle shows sporadic potentials as in inhalation, and should probably be classified as showing no activity related to the test maneuver, but the constant activity of the longissimus muscle in this position made evaluation impossible.

4. Complete flexion

a. Inspiration

The iliocostalis and longissimus muscles showed potentials with low amplitude (4).

b. Expiration

The iliocostalis and longissimus showed potentials with large amplitude (3).

Subject five:

J.K. (male)(right side)

1. Erect standing position

a. Inspiration

The iliocostalis muscle shows potentials of low amplitude (4).

The longissimus muscle shows potentials of moderate amplitude (3).

b. Expiration

The iliocostalis muscle shows potentials of low amplitude (4).

The longissimus muscle shows no activity.

2. In speaking

The longissimus muscle shows potentials throughout the recitation of the nursery rhyme but the iliocostalis muscle cannot be properly evaluated due to the unsteady base line.

3. Partial flexion

a. Inspiration

The iliocostalis muscle shows an increase in the number of potentials and a decrease in the amplitude (4).

The longissimus muscle shows potentials of moderate amplitude (3).

b. Expiration

The iliocostalis muscle shows short bursts of amplitude (4).

The longissimus muscle shows potentials of moderate amplitude (3).

4. Complete flexion

a. Inspiration

The iliocostalis muscle shows potentials of very low amplitude (4).

The longissimus muscle shows no activity.

b. Expiration

The iliocostalis muscle shows potentials of very low amplitude (4).

The longissimus muscle shows no activity.

Subject six:

A.S. (female) (right side)

1. Erect standing position

a. Inspiration

The iliocostalis muscle shows potentials of moderate amplitude (3).

The longissimus muscle shows potentials of low amplitude (4).

b. Expiration

The iliocostalis muscle shows potentials of moderate amplitude (3). These potentials are larger than the ones shown in inspiration.

The longissimus muscle shows potentials of moderate amplitude (3).

2. In speaking

The iliocostalis and longissimus muscles showed a few sporadic bursts of activity but no correlation can be made with any word or groups of words.

3. Partial flexion

a. Inspiration

The iliocostalis and longissimus muscles showed potentials with moderate amplitude (3).

b. Expiration

The iliocostalis and longissimus muscles showed potentials of low amplitude (4).

4. Complete flexion

a. Inspiration

The iliocostalis muscle shows potentials with moderate amplitude (3).

The longissimus muscle shows potentials with low amplitude (4).

b. Expiration

The iliocostalis muscle shows potentials with moderate amplitude (3).

The longissimus muscle shows potentials with low amplitude (4).

<u>Subject seven</u>:

L.H. (female) (right side)

1. Erect standing position

a. Inspiration

The iliocostalis and longissimus muscles showed potentials with low amplitude (4).

b. Expiration

The iliocostalis muscle shows potentials of moderate amplitude (3).

The longissimus muscle shows potentials of large amplitude (3).

2. In speaking

The iliocostalis and longissimus muscles showed definite activity during the recitation but the records do not reveal any correlation between any word or words because the apparatus is not sensitive enough to record these fine variations. This record is the only one of the ten subjects that actually showed definite activity in the iliocostalis muscle during speech.

3. Partial flexion

a. Inspiration

The iliocostalis and longissimus muscles showed no activity.

b. Expiration

The iliocostalis and longissimus muscles showed no activity beyond that caused by the muscle being in the partial flexed position.

4. Complete flexion

a. Inspiration

The iliocostalis and longissimus muscles showed action potentials of reduced amplitude (4).

b. Expiration

The iliocostalis and longissimus muscles showed potentials of moderate amplitude (3).

Subject eight:

A.H. (male) (right side)

1. Erect standing position

a. Inspiration

The iliocostalis muscle shows no activity.

The longissimus muscle shows potentials of small amplitude (4).

b. Expiration

The iliocostalis and longissimus muscles showed potentials of large amplitude (3).

2. In speaking

In the iliocostalis muscle no activity could be observed.

In the longissimus muscle only sporadic bursts of activity could be seen and there may have been some association with certain words.

3. Partial flexion

a. Inspiration

The iliocostalis and longissimus muscles showed no activity associated with the test maneuver.

b. Expiration

The iliocostalis muscle shows potentials of large amplitude (3).

The longissimus muscle shows no activity beyond that demonstrated by this muscle while in this position.

4. Complete flexion

a. Inspiration

The iliocostalis muscle shows potentials with moderate amplitude (3).

The longissimus muscle shows no activity.

b. Expiration

The iliocostalis muscle shows potentials with very large amplitude (3).

The longissimus muscle shows potentials with very

low amplitude (4).

<u>Subject nine:</u>

E. H. (female) (right and left side)

1. Erect standing position

a. Inspiration

The iliocostalis and longissimus muscles show potentials of low amplitude (4).

b. Expiration

The iliocostalis and longissimus muscles show potentials with moderate amplitude (3), although the potentials of the longissimus muscle are larger.

2. In speaking

There seems to be no activity in the right iliocostalis muscle but some activity in the left iliocostalis muscle was observed.

There is definite activity in the right longissimus muscle and some activity was seen in the left longissimus muscle.

Again the technique does not allow a correlation of the activity with any words or phrases.

3. Partial flexion

a. Inspiration

The iliocostalis muscle shows no activity.

The longissimus muscle shows potentials of moderate amplitude (3).

b. Expiration

The iliocostalis muscle shows potentials of low amplitude (4).

The longissimus muscle shows no activity beyond that caused by the muscle assuming this position.

4. Complete flexion

a. Inspiration

The iliocostalis muscle shows no activity.

The longissimus muscle shows potentials of low amplitude (4).

b. Expiration

The iliocostalis and longissimus muscles showed potentials of low amplitude (4).

Subject ten:

B.W. (male) (right side)

1. Erect standing position

a. Inspiration

The iliocostalis and longissimus muscles showed potentials of low amplitude (4).

b. Expiration

The iliocostalis and longissimus muscles showed potentials of moderate amplitude (3).

2. In speaking

Action potentials are shown in the iliocostalis muscle and longissimus muscle. The technique does not allow a correlation of the activity with any words or phrases.

3. Partial flexion

a. Inspiration

Both the iliocostalis and the longissimus muscles showed potentials of very large amplitude (3).

b. Expiration

The iliocostalis muscle shows potentials of very large amplitude (3).

The longissimus muscle shows potentials largely increased in amplitude (3).

4. Complete flexion

a. Inspiration

The iliocostalis and longissimus muscles showed potentials that are low in amplitude (4).

b. Expiration

The iliocostalis muscle showed potentials of moderate amplitude (3).

The longissimus muscle showed potentials of low amplitude (4).

CHAPTER IV

DISCUSSION AND CONCLUSION

A. Mechanics of Erect Posture.

The body is supported by the feet as a base (the lower limbs are supporting pillars) and the back is constructed as the vertical support to hold the torso erect to meet the exigencies of everyday living.

The center of gravity of the body is located (according to Morton 1952) by "dropping a plumb line from external auditory meatus. This line will fall in front of the ankle between the two navicular bones." In a review paper on the center of gravity in relation to standing (Brunnstron 1954) concludes "a perpendicular through the center of gravity tends to fall near the center of the base of support."

The spinal column has a thoracic primary anteriorly concave curvature with secondary lumbar and cervical anteriorly convex curves; thus the arrangement of the vertebrae in the "S" curve enables the back to be flexible to accept the jarring of the body caused by walking and maintain a center of gravity located more posteriorly than anteriorly of the total body volume.

The bodies of the vertebrae may be compared to blocks

whose individual sizes increase from above downward, that have been stacked one on top of the other and these blocks are prevented from slipping by the intervertebral discs and by the distribution of forces as noted above. If the ligaments limited the vertebrae to this position, movement would be impossible. That the erector spinae muscles are not responsible for holding the body erect is shown by the electrical silence which is exhibited in the records made in this study and others (Weddell, Feinstein and Pattle 1944; Floyd and Silvers 1955; Campbell 1958).

The erector spinae muscles are brought into play when the center line of gravity shifts forward; Beevor (1904) has shown that when the arm is flexed in front of the body or the neck is slightly moved either anteriorly or posteriorly both erector spinae muscles contract. If the flexed arm is slowly abducted through an angle of fourty-five degrees the ipsilateral erector spinae muscle relaxes and the contralateral one contracts. Beevor (1904) continues with the analysis by asking whether it is possible to advance the humerus without bringing the erector spinae muscles into action. If while the arm is flexed the erector spinae muscles relax and if the arm is dropped and the maneuver is repeated no contraction of the

erector spinae muscles will take place. The reason is because the weight behind the center of gravity now equals the weight of the flexed arm. In other words, with the redistribution of forces there is no need for the erector spinae muscles to be altered. Thus, only when the body is flexed through a certain critical angle do the erector spinae muscles contract to hold the body in that flexed position.

After complete flexion of the body has taken place the back muscles cease to work and the task of holding the body in this position is performed solely by the ligaments, (Floyd and Silvers 1955; Campbell 1958). The muscles from a metabolic viewpoint are expensive and the ligaments can perform this task of holding the body much more cheaply. (See Morton 1952, chapter 32, Metabolic Economy in Muscle Function.)

B. Action of Muscles in Erect Standing Position.

One of the primary tasks of the erector spinae muscles is to hold the body in various postural attitudes while a second task is to extend the trunk. Another task of the back musculature is to assist in respiration when large amounts of air must be exchanged, as in running. (Floyd and Silvers 1955; Campbell 1958)

In this study it was seen that in the erect standing

position 83% of the males and 100% of the females showed action potentials in the iliocostalis muscle during the terminal phase of deep inspiration. In the longissimus muscle during inspiration 100% of the males and females showed action potentials. During expiration 100% of the males and females showed action potentials in the iliocostalis muscle while in the longissimus muscle during expiration 83% of the males and 100% of the females showed action potentials. (See Appendix V for summary table.)

1. Iliocostalis muscle:

a. Respiration

Campbell (1958) showed that the iliocostalis muscle is used both in inspiration and expiration even though Duchenne (1867) has stated that no muscle can perform two antagonistic actions.

It is postulated here that the iliocostalis muscle is not performing two antagonistic actions but one continuous one. The iliocostalis muscle is not being used to elevate the ribs but simply to "fixate" them so that a deeper inspiration is possible via the action of the diaphragm. The above statement is supported by the electromyographic data which shows action potentials during deep inspiration. Most of the subjects

showed a low amplitude pattern probably because the contraction of the iliocostalis muscle is only sufficient to just "fixate" the ribs.

Presumably during expiration the iliocostalis muscle contracts and depresses the ribs causing a powerful expiratory action. The muscle is attached laterally to the inferior border of the ribs and by pulling exerts a powerful expiratory effect.

The iliocostalis muscle then probably has four actions; two principal and two auxillary:

1. the principal actions are:
   a. to extend the trunk, but not studied here (Floyd and Silvers 1955)
   b. to hold the body in certain postural attitudes (Floyd and Silvers 1955)
2. the auxillary actions are:
   a. to "fixate" the ribs which allows the diaphragm to make a large contraction during inspiration
   b. possibly to depress the ribs and effect maximum expiration.

b. In Phonation

The activity of this muscle in the act of phonation cannot

be evaluated in this paper because action potentials were definitely shown in only one subject. This muscle may have no role in phonation.

2. Longissimus muscle:

a. Respiration.

This muscle is probably being used to compensate for an anterior displacement of the center of gravity by the forward moving ribs and thoracic mass during inspiration. The records obtained in this study show that during inspiration 100% of the subjects showed activity during inspiration while during expiration 90% of the subjects showed activity in this muscle.

When the longissimus muscle contracts the spinal column is extended. Dally (1909) showed by means of roentgen examination (orthodiagraphic) that "the shadow of the vertebral column is seen clearly separated off from that of the pericardium and the great vessels by a transradiant triangle, the base of which is formed by the upper surface of the diaphragm.

On inspiration the posterior wall of this triangle formed by the spinal column is seen to recede to a greater extent below than above, so as to open out the interval from before backwards. With subsequent expiration the spine advances. On inspiration the shoulders are squared and the head elevated

and thrown backwards, then there is a gradual backward movement of the whole thoracic spine as far as the superior scapular angle, in consequence of this in deep breathing the upper thoracic region is widened anterior-posteriorly."

The longissimus muscle then has two primary functions like the iliocostalis muscle and possibly two auxiliary:

1. the principal actions are:
   a. to extend the trunk, but not studied here (Floyd and Silvers 1955)
   b. to hold the body in certain postural attitudes (Floyd and Silvers 1955)
2. the auxiliary actions are:
   a. to possibly aid the iliocostalis muscle in depressing the ribs, particularly the lateral attachments of the longissimus muscle.
   b. medial attachment to vertebrae for extending column. (additional to primary extension)

The "fixating" of the ribs by this muscle could not explain Dally's (1909) observation. This muscle probably acts by its medial set of attachments to extend the spine. This study does not indicate the division of the work between medial and lateral attachments.

b. In Phonation:

The longissimus muscle is the largest of the three elements of the erector spinae muscles and the longissimus muscle showed the greatest number of action potentials with speech. The muscle probably helps to balance the anterior postural muscle group in achieving voice control but the data is lacking from this experiment which would support this statement.

Nothing could be found in the literature as to the action of the back muscles in speech.

C. The Action of Muscles in Partial Flexion

1. Iliocostalis muscle

a. Respiration

The same activity of the iliocostalis muscle is postulated for this position as was found in the erect standing position. The only difference is that greater activity is required by the muscle while in this position since this muscle must contract to hold the body in this attitude. The number of subjects which showed action potentials in this muscle during inspiration while in the partially flexed position was 50% of the females and 66% of the males

2. Longissimus muscle:

a. Respiration

The longissimus muscle showed action potentials during partial flexion in 50% of the males and females with an amplitude of moderate height during inspiration. This muscle is extending the spine during inspiration and concomittantly keeping the body in a flexed position.

D. Action of the Muscles in Complete Flexion

In complete flexion there is no activity of the erector spinae muscles until deep inspiration and expiration take place. The activity is the same in the iliocostalis muscle as in the longissimus muscle. The postulate advanced here is that the pressure of the diaphragm upon the viscera causes the longissimus muscle and iliocostalis muscle to contract to "Fixate" the ribs to enable the diaphragm to gain a greater contraction.

Thus no matter if the body is in the erect standing position, partially flexed position or completely flexed position the activity of the iliocostalis and longissimus muscles remain the same. The function of the iliocostalis muscle, it is proposed, is to "fixate" the ribs so that a greater diaphragmatic excursion is possible during inspiration; during expiration the iliocostalis muscle diminishes the size of the thoracic cavity. The function of the longissimus muscle during inspiration is to extend the vertebral column while during expiration

the function is to assist the iliocostalis muscle in diminishing the thoracic cavity. The above statements are confirmed by direct observation and by electromyography.

E. Conclusions:

1. The iliocostalis and longissimus muscles are active in all three positions during the same phases of the respiratory action.

2. During inspiration the iliocostalis muscle is apparently "fixating" the ribs for a better diaphragmatic action.

3. During expiration the iliocostalis muscle probably depresses the ribs and flexes the vertebral column.

4. The longissimus muscle in all three positions is apparently extending the vertebral column; its medial attachments are probably active.

5. The longissimus muscle is active during expiration and its lateral set of attachments are probably active during this phase.

CHAPTER V

SUMMARY

1. The iliocostalis and longissimus portions of the erector spinae muscles were studied electromyographically in three positions: erect standing, partially flexed, and completely flexed positions.
2. Surface electrodes with the Grass IIID Model EEG were employed in recording action potentials.
3. These muscles of the back were studied in 10 subjects (4 females and 6 males). Each subject was studied in the three positions noted.
4. The iliocostalis muscle is active during inspiration.
5. The postulate is that the muscle is probably active because it is "fixating" the ribs allowing better diaphragmatic action.
6. The iliocostalis muscle is active during expiration.
7. The postulate advanced is that the muscle is depressing the ribs.
8. The longissimus muscle is active during inspiration.
9. The postulate is that the muscle is extending the vertebral spines which is confirmed by Dally (1909).

10. The longissimus muscle is active during expiration.

11. The activity is probably associated with assisting the iliocostalis muscle in depressing the ribs.

12. There is no significant difference between males and females in the functioning of the back muscles.

13. The assessment of the back muscles during speech cannot be made from this study because the frequency response of the apparatus was too low, or they may have no role.

ANNOTATED LITERATURE

Akerblom, B. 1948 Standing and sitting posture, Stockholm, A.-B. Nerdiska Bokhandeln.
Examination of the literature in standing and sitting positions especially in reference to the construction of a good chair. In regard to the back muscles there is stated on page 178 "one may take the view that sitting relaxed, sunken and bent forwards should be a good resting position. Electromyography of the lumbar part of the sacrospinalis also shows that the muscles of this region are practically inactive."

Beevor, C.E. 1904 The Croonian lectures on muscular movements and their representation in the central nervous system. London, Adlard and Son.
A series of four lectures on the movements of upper extremity, of the head, of the spinal column and representation of the movements in the central nervous system. The techniques used for investigating the muscles are analysed; the author uses the method of palpation while asking the subject to perform an action.

Brunnstrom, S. 1954 Center of gravity line in relation to ankle joint in erect standing. The Phy. Ther. Review 34: 109-115.
A critical review is given of center of gravity of Braune and Fischer's Normalstellung. This position is illustrated and contrasted with the Bequeme Haltung, the latter being assumed when one stands naturally. The conclusion of the author is based upon Hilerbrandt's work: "a perpendicular through the center of gravity tends to fall near the center of the base of support." A very valuable review article.

Campbell, E.J.M. 1958 The respiratory muscles and the mechanics of breathing. Chicago, Year book Publishers Inc.
An investigation and correlation of activity of back muscles as observed with electromyography. A must for a better understanding of respiratory mechanics and physiology. The bibliography is very extensive and comprehensive. In the appendix is valuable information of electromyography technique.

Dally, J.F.H. 1909 An inquiry into the physiological mechanism of respiration with special reference to the movements of the vertebral column and diaphragm. London, J. Anat. 43, 93-114
The ~~x~~-ray examination (orthodiagraphic) examination of the movement of the vertebral column during respiration is discussed. Also the important role of the erector spinae muscles is emphasized in respiration. Three diagrams are shown of the diaphragm in inspiration and expiration. No bibliography is given.

Duchenne, G.B.A. 1867 Physiologie des Mouvements Trans. E.P. Kaplan 1949 Philadelphia, Lippincott.
A study of practically all the muscles in the body in the healthy and individuals in which there was muscular disease or muscles anomalies or absences. The author stimulated the muscle electrically and observed the effect obtained. Criticism of Duchenne's work is that even though a muscle may be capable of some movement when stimulated electrically it may act in this manner rarely or never under physiological conditions.

Floyd, W.F. and Silvers P.H.S. 1952 Comparitive merits of ink-writer and cathode ray oscillographs for electromyography. J. Phys. 117 London 36P, 37P.
The author determined the response of ink writer to signals of known amplitude and wave form and by simultaneous recordings of muscle action potentials by ink writer and oscillographs. The conclusions are: There is a steady state response. The response is constant up to 50 c/s. 50-70 c/s resonance with not more than 70% increase in amplitude the response declined 100 c/s it was 25-35% of the amplitude below resonance. There is no loss of significant information for monopolar needles or for surface electrodes leads, using the ink-writer.

Floyd, W.F. and Silvers P.H.S. 1955 The function of Erector Spinae muscles in certain movements and postures in man. J. Phys. 129 London 184-203
The erector spinae muscles were examined electromyography at levels of 13,14,15 with needle and surface electrodes in erect standing, partially flexed and completely flexed positions. The erector spinae muscles

were shown to be electrically active during partial flexion. The ligaments support the body after complete flexion is reached.

Grant, J.C.B. Morris' Human Anatomy Edited by Schaeffer, 10ed. Philadelphia, Blakiston Co.
In this section on musculature under superficial lateral dorsal system of back muscles Grant states "The iliocostalis lumborium depresses the ribs while the iliocostalis cervices may aid in elevating them. The spinalis serves merely as an extensor."

Kelton, I.W. and Wright R.D. 1949 The mechanism of easy standing by man. Aust. J. Exp. Biol. Med. Sci. 27: 505-515.
Electromyographic and gravimetric determinations were carried out in several subjects (number not stated) on the muscles of the leg, thigh, dorsal spinal and mandibular muscles. All were found to be electrically silent except tibialis anterior and solus muscles in easy standing position, which is well defined by the auther.

Licht, E.S. 1956 Electrodiagnosis and electromyography. Baltimore waverly Press inc.
A detailed history of electromyography and mechanics of electromyography is given in the first two chapters, muscle physiology and motor points constitute the next two chapters. The rest of the book discusses Electrodiagnosis with one chapter on electroencephalography and one chapter on electroretinography. The book is largely clinical, written by many physicians for physicians in physical medicine.

Morton, D.J. and Fuller D.D. 1952 Human locomotion and body form. Baltimore, Williams and Williams Co. 285.
A detailed analysis of walking and mechanics of foot; the book is amply illustrated. Probably the best chapters are chapter 32 on Metabolic economy in muscle functionand chapter 28 on Postural and locomotion habits.

Pauly, J.E. 1952 Electromyographic studies of some muscles of respiration. M.S. Thesis, Loyola Univ.
Electromyographic examination of the intercostals spaces in two places i.e. intercartilaginous

portions of the internal intercostals and in mid clavicular line. The two intercostals are studied together. The conclusion is that during eupnea and hyperpnea the above muscles contract for purpose of maintaining the space between the ribs.

Thane, G.D. and Schafer E.A. Editors of Quain's Elements of Anatomy 1899 10ed., Vol. II London, Longmans, Green and Co.
A book of descriptive myology and angeiology. Exsellent plates of the muscles are shown. Brief discussions are given about morphology of the limb and trunk muscles.

Walmsley, T. 1923 Quain's Elements of Anatomy. Edited by T.H. Bryce, 11 ed. Vol. IV Part II London, Longmans, Green and Co.
A very valuable introduction is given developing the topics of structure, mechanics and morphology of the skeletal muscles. The rest of the book is descriptive myology, with analysis of complex actions in the body and participation of the muscles in that action.

Weddell, B. and Feinstein, P.E. and Pattle, R. 1944 The electrical activity of voluntary muscle in man under normal and pathological conditions. Brain 67: 178-257
No electrical activity could be recorded from a voluntary muscle when it is completely relaxed. A discussion of muscle tone and factors responsible are listed according to body compartments; rheological and central nervous system. The rest of the paper is divided into sections: Action potentials for denervated muscle, a case of reversible ischaemic nerve block, and re-innervated muscle. In the last chapter is discussed specific neurologic affections.

QUESTIONNAIRE Record No.

APPENDIX 1 (SAMPLE SHEET) 54.

1. Name ____________ Race ______ Sex ________

2. Occupation ________________________

    a) does occupation involve sitting at a desk? Yes ___ No ____
    b) if yes, how long? _____ hrs. _____ minutes per day
    c) how many hours a week do you work?
    d) does your job involve climbing of stairs? Yes ___ No _____
    e) if yes, how many flights?

3. Do you drive a car? Yes ___ No ____
    a) if yes, do you drive to work?
    b) if yes to 3a, how long does it take to drive to work?
    c) approximately how much time do you spend in the car in a week? hrs. ______

4. Do you do active exercise at present? Yes ___ No _____
    a) Is this activity obtained through definite scheduled classes? ___ hrs./wk.
    b) What exercises are done routinely in these classes?

5. If <u>No</u> to 4, then do you exercise (underline one)
    Never   2-3 times a week   once a month
    a) What type of exercise is done if you exercise at all?

6. What is your favorite sport?

7. Do you actively participate in the sport?

8. Have you ever had an injury to your back?
    a) were you disabled for any length of time with this injury? Yes No
    b) how long

9. Have you ever had an injury to your abdomen? Yes ___ No _____
    a) type of injury? ________________________

10. Have you ever had an operation on your abdomen? Yes ___ No _____
    a) state what was done ________________________
    b) year

11. Have you ever injured your chest or lungs in any way? Yes ___ No _____
    a) state what happened and year ________________________

12. Have you ever broken your arm or injured your shoulder in any way? Yes ___ No ___
    a) state what happened and year ________________________

13. Remarks:

APPENDIX II (SAMPLE SHEET)

EMG DATA

DATE ____________________

Calibration ____________ paper speed _______ power amp. _______ equalizing _______

side used   Right ______ Left ______   Total Width ________ Ground site ________

Channel	Setting of switches G_1 and G_2	Placement of electrodes	Muscle
1.			
2.			
3.			
4.			
5.			
6.			

APPENDIX III TABLE I SUMMARY OF A SCHEME OF INSERTION AND ORIGIN OF M. erector spinae

SUPERFICIAL LAYER

Level	LATERAL COLUMN	MEDIAL COLUMN	MEDIAN COLUMN
Lumbar	M. iliocostalis lumborum Origin: Common aponeurosis entire sacral groove, sacrotuberous ligament and medial 1/3 of ilium. Insertion Inferior border of lower six ribs medial to the posterior angles.	M. longissimus thoracis COMMON Insertion Laterally: into all ribs (1-12) medial to M. iliocostalis Medially: into transverse processes of all thoracic vertebrae and accessory processes of upper three lumbar vertebrae	M. spinalis thoracis ORIGIN Also from the medial aspect of M. longissimus and upper two or three spinous processes of lumbar vertebrae. Insertion upper six thoracic spinous processes by 4-8 tendons.
Thoracic	thoracis Origin: Medial to the insertion of M. iliocostalis lumborum on the superior surface of the six lower ribs. Insertion: inferior surface of upper six ribs medial to the insertion of M. iliocostalis lumborum	cervicis Origin: transverse processes of the upper six thoracic vertebrae medial to the insertion of M. longissimus thoracis.	
Cervical	cervicis Origin: superior surface of upper six ribs medial to the insertion of M. iliocostalis thoracis. Insertion: posterior tubercles of transverse processes of cervical vertebrae four through six.	Insertion: posterior tubercles of transverse processes of cervical vertebrae from second through fifth.	(Rare) cervicis Origin: seventh cervical spinous process. Insertion: spinous process of axis.
Occipital		capitus Insertion: posterior margin of mastoid process.	capitus Origin: upper cervical vertebrae in common usually with M. semispinalis capitus Insertion: between inferior and superior nuchal lines of skull.

APPENDIX IV

TABLE II

RECORDS OF INDIVIDUALS DURING RESPIRATION IN THE THREE POSTURAL ATTITUDES

		Iliocostalis Muscle			Longissimus Muscle		
		Insp.	Exp.	Speech	Insp.	Exp.	Speech
Subject 1	E	4	3	1	4	3	1
	P	3	3		3	3	
	F	4	1		2	1	
Subject 2	E	4	3	1	4	3	1
	P	1	1		1	1	
	F	3	3		3	4	
Subject 3*	E	3	4	1	3	4	2
	P	3	4		4	4	
	F	4	1		4	1	
Subject 4	E	4	4	1	4	4	1
	P	3	3		2	2	
	F	4	3		4	3	
Subject 5	E	4	4	1	3	1	3
	P	4	4		3	3	
	F	4	4		1	1	
Subject 6*	E	3	3	2	4	3	2
	P	3	4		3	4	
	F	3	3		4	4	
Subject 7*	E	4	3	3	4	3	3
	P	1	1		1	1	
	F	4	3		4	3	
Subject 8	E	1	3	1	4	3	1
	P	1	3		1	1	
	F	3	3		1	4	
Subject 9*	E	4	3	2	4	3	3
	P	1	4		3	1	
	F	1	4		4	4	
Subject 10	E	4	3	3	4	3	3
	P	3	3		3	3	
	F	4	3		4	4	

Code:
- E: Erect standing position
- P: Partial flexed position
- F: Complete flexed position
- 1: No activity
- 2: Sporadic activity
- 3: Activity associated with test maneuver
- 4: Activity associated with test maneuver but low amplitude
- *: Female

Blank spaces indicate items not studied.

APPENDIX V

TABLE III

SUMMARY TABLE OF EXPERIMENTAL RESULTS

		Inspiration				Expiration			
Position	Muscle	1	2	3	4	1	2	3	4
Erect	Iliocostalis	1/0 16/0		0/2 0/50	3/2 83/50			4/3 66/75	2/1 33/25
	Longissimus			1/1 16/25	5/3 83/75	1/0 16/0		4/3 66/75	1/1 16/25
Partial Flexion	Iliocostalis	0/2 0/50	2/0 33/0	3/2 50/50	1/0 16/0	0/1 0/25	1/0 16/0	4/0 66/0	1/3 16/75
	Longissimus	1/1 16/25	2/0 33/0	3/2 50/50	0/1 0/25	2/2 33/50	1/0 16/0	3/0 50/0	0/2 0/50
Complete Flexion	Iliocostalis	0/1 0/25		2/0 33/0	4/3 66/75	1/1 16/25		3/2 50/50	2/1 33/25
	Longissimus	2/0 33/0	1/0 16/0	1/0 16/0	2/4 33/100	2/1 33/25		1/1 16/25	3/2 50/50

Code: Male/Female
%/%

APPENDIX VI

FIGURE 7a

AVERAGE TRACING

APPENDIX VII

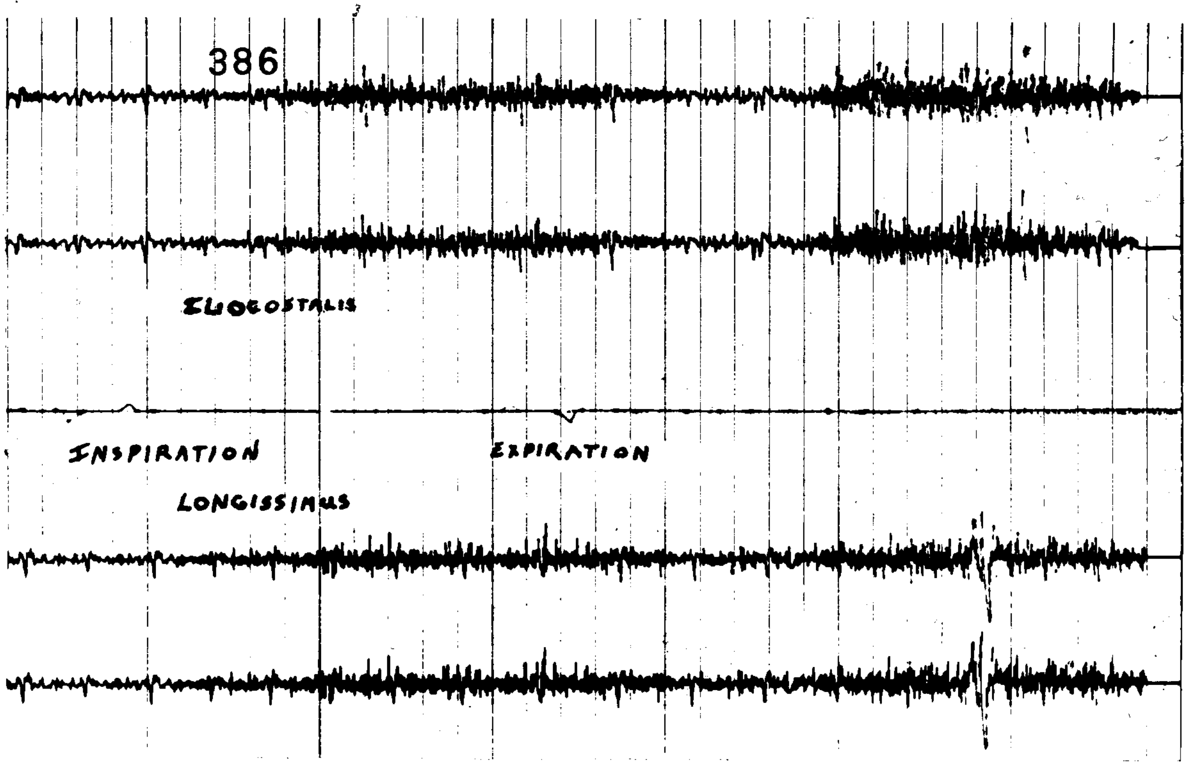

FIGURE 7b

AVERAGE TRACING

APPENDIX VIII

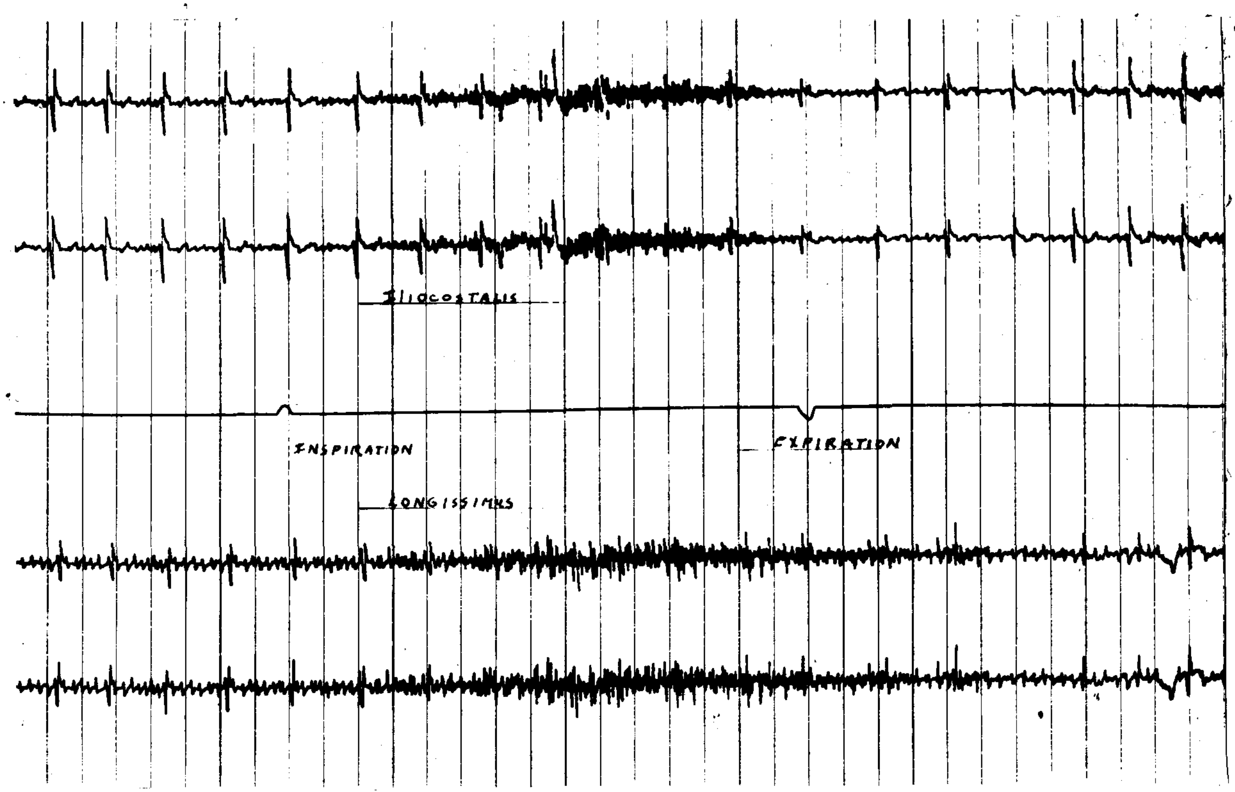

FIGURE 8

TRACING SHOWING EARLIEST ONSET

OF ELECTRICAL ACTIVITY

APPENDIX IX

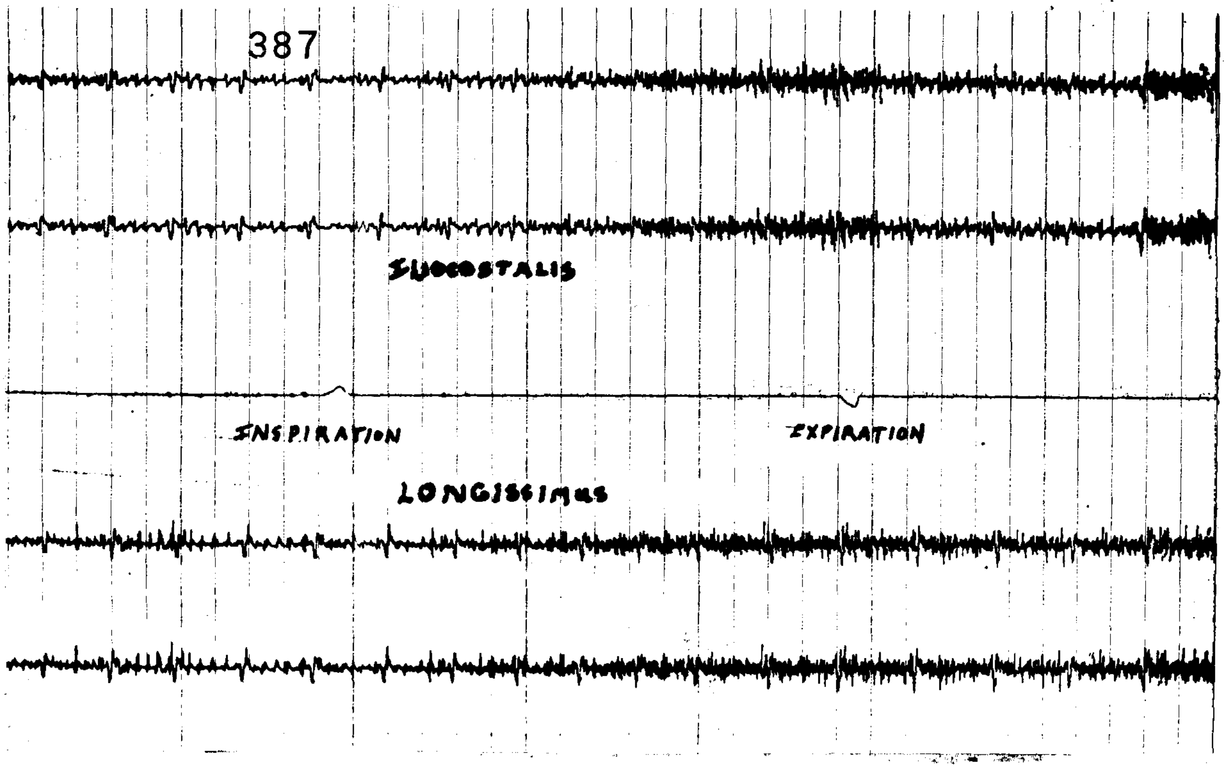

FIGURE 9

TRACING SHOWING LATEST ONSET
OF ELECTRICAL ACTIVITY

APPENDIX X

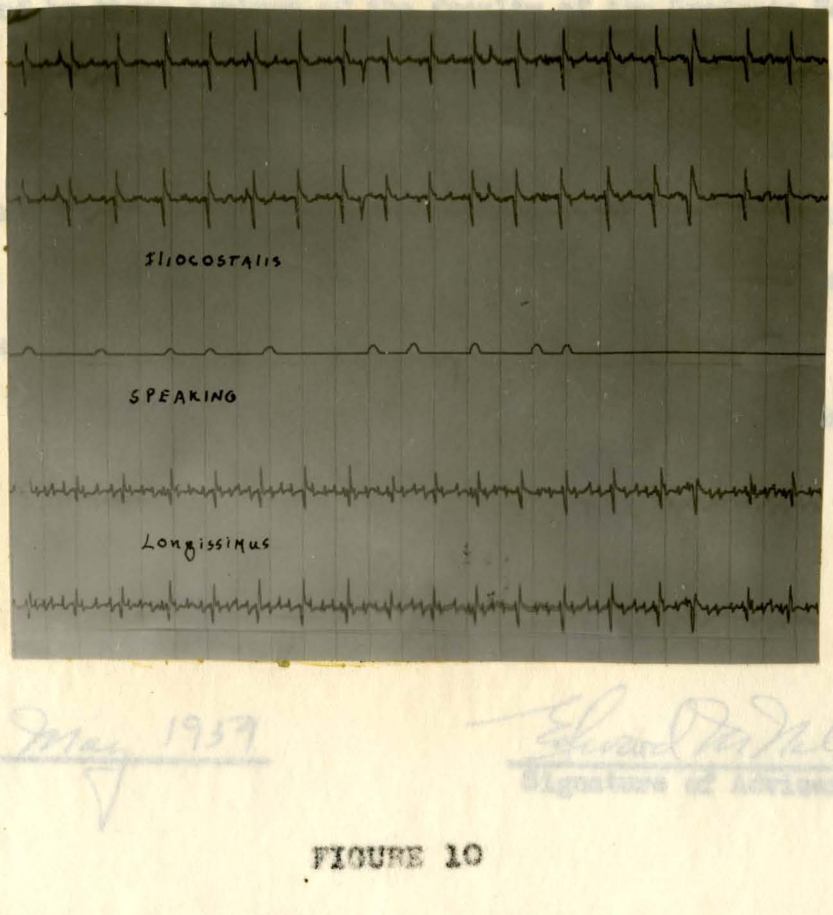

FIGURE 10

TRACING DURING SPEECH

APPROVAL SHEET

The thesis submitted by Albert A. Halls has been read and approved by three members of the faculty of the Graduate School.

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.

25 May 1959
Date

Edward M. Nelson
Signature of Adviser