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An Electromyographic Study of the Effects of Lateral Asymmetry on the Upper Leg Muscles Used in Normal Walking on a Treadmill

S. Marie Landmesser
Eastern Illinois University

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AN ELECTROMYOGRAPHIC STUDY OF THE EFFECTS OF LATERAL ASYMMETRY ON THE UPPER LEG MUSCLES USED IN NORMAL WALKING ON A TREADMILL

(TITLE)

BY

S. Marie Landmesser

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INTRODUCTION

The study of humans in motion has been intriguing man for centuries. The first recordings of studies in muscular function appeared in the Renaissance period when Leonardo da Vinci,[1] besides bending his genius to art, directed much thought to analyzing the muscles of man and their function. Andreas Vesalius,[2] who is acknowledged as the "father" of modern anatomy, was also concerned with the functioning of muscles. However, the early pioneers in medical science were limited to investigating the muscles of man by studying "dead"[3] muscles.

In the eighteenth century medical science received a new jolt of life and interest from Galvani[4] and his experiments with nerve-muscle preparations and animal electricity. Through the work of Galvani scientists became aware of the fact that skeletal muscles will contract when stimulated electrically and, conversely, that contracting muscles produce a minute, but detectable, electrical current when contracting.

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[1]J. V. Basmajian, Muscles Alive, Their Functions Revealed by Electromyography (Baltimore: The Williams and Wilkins Co., 1967), p. 1.

[2]Ibid.

[3]Ibid. "Dead" muscles refers to the muscles studied in cadavres.

[4]Ibid., p. 4.

This led to the modern use of electrocardiography, electroencephalography, and electromyography. Electromyography, although closely related to the latter two technical innovations, was somewhat delayed in its development. Not until the Frenchman, Duchenne,[5] applied the use of electricity to determine the dynamics of intact skeletal muscles, did electromyography become known.

According to Basmajian,[6] the relative lateness of electromyography, when compared to electrocardiography and electroencephalography, was due to the lack of reliable apparatus. World War II, with its many demands on technology, remedied this situation. With the advent of better equipment, electromyography no longer remained only within the domain of neurologists and physiotherapists, but became of interest to physiologists and anatomists. Soon electromyographical studies were being conducted, published, and accepted.

Adrian and Bronk[7] at Oxford in 1929, developed the concentric needle electrode. This discovery allowed electromyography to take another step forward by permitting the tapping of deep muscles, individual muscles rather than muscle groups, and even individual muscle units within a specific muscle.

Clinical electromyography became a matter of course and many publications of a variety of neuromuscular dysfunctions were the result. Some of the leading investigators in electromyography were Scandinavians, notably, Buchthal, Kugelberg, and Clemmesen.[8]

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[5]Ibid.

[6]J. V. Basmajian, "Electromyography," University of Toronto Medical Journal (Volume 30, October, 1952), p. 10.

[7]Ibid., p. 11.

[8]Ibid.

Electromyography was not confined to the use of clinical diagnosis. Inman, Saunders, and Abbott[9] of California determined the muscle function for the shoulder region. This was one of the first electromyographical studies applied to the function of the muscles of man. As a result many more studies by anatomists and kinesiologists were compiled. Physical educators also became interested and conducted electromyographical investigations pertaining to the function of specific muscles during specific sport skills.

In the majority of the studies conducted by physical educators, the subjects used were highly skilled athletes with, more likely than not, normal skeletal structures; however, it could conceivably have been that some subjects had a postural fault caused by a deviation in this skeletal alignment and that this problem had an effect on the outcome of the electromyograms. Proof of this statement was difficult to obtain since very few investigators mentioned the skeletal structure of their subjects.

Structural deviations, or structural imbalance, relates closely to functional efficiency, which in turn is determined by the function of the muscles working on the skeletal lever system. Huelster agreed in her paper, "The Relationship Between Bilateral Contour Asymmetry in the Human Body in Standing and Walking,"[10] that this was a fact that had been generally accepted. Davies wrote that

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[9]Ibid.

[10]Laura J. Huelster, "The Relationship Between Bilateral Contour Asymmetry in the Human Body in Standing and Walking," The Research Quarterly (Volume 24, March, 1953).

> balanced posture enables one to have graceful and efficient movement. If a person's body is out of alignment or is asymmetrical, he is expected not to have efficient movement patterns.[11]

If a person does not have efficient movement patterns it is logical to conclude that this lack of efficiency might occur in the muscular activity. A person with a postural defect might compensate for that defect. If the muscles are not functioning efficiently, this inefficient function might be recorded on electromyograms. The thoughts on this observation led to this study.

STATEMENT OF THE PROBLEM

The investigation entailed a comparative study of ten female subjects to determine through electromyography the effects of lateral asymmetry of the pelvis on the muscles of the upper leg when employed in walking on the treadmill. The study involved the use of two groups of subjects: Group A consisted of five female subjects who demonstrated lateral asymmetry as defined by the paper and Group B consisted of five reference subjects designated as having no lateral asymmetry.

IMPORTANCE OF THE STUDY

Many electromyographical studies have been compiled over the years. It appeared that the subjects, studied by kinesiologists and physical educators, primarily concerned with electromyography as a tool to determine muscle activity in specific sports skills, were

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[11]Evelyn A. Davies, "Relationship Between Selected Postural Divergencies and Motor Ability," The Research Quarterly (Volume 28, March, 1957), p. 1.

"normal" in skeletal structure. Similarly it seemed that the medical investigators who carried out the first electromyographical studies to determine the precise functions of specific muscles, also used subjects who were "normal" in skeletal structure. The only study encountered by the writer which took into account the skeletal structure of the subjects was entitled, "Electromyographic Study of the Iliopsoas Muscle."[12] In the study the authors stated of the subjects, "none had any gross abnormalities which would alter the normal kinesiology of the hip."[13] The inclusion of this statement by Le Ban, et al. indicated that skeletal structure of the hip could be an important consideration when studying the function of any of the muscles that involve the hip joint.

The investigators of muscular function as related to sports skills were interested in the ability of their subjects to carry out the selected skill rather than the skeletal structure of the subject. Since skeletal structure was not recorded, it could conceivably be that a deviation in skeletal structure could have had a bearing on the results of certain electromyographical studies. This led to the speculation that a specific deviation in skeletal structure, in this case lateral asymmetry of the pelvis, might have changed the outcome of an electromyographical study. Specifically, would a person with a structural deviation such as lateral asymmetry of the pelvis, use the same muscles in performing a specific movement as would a person with no lateral asymmetry of the skeletal system?

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[12]Myron M. Le Ban, et al., "Electromyographic Study of Iliopsoas Muscle," Archives of Physical Medicine and Rehabilitation (October, 1965), XLVI, p. 676.

[13]Ibid.

HYPOTHESIS

The study involved the problem of determining whether or not lateral asymmetry effected the muscular activity of a person while walking and if the affects would be demonstrated in the muscle action potentials recorded on electromyograms. In order to present the results of the study a null hypothesis was formulated. The general hypothesis tested was:

There would be no difference in the action potentials of certain muscles in the upper leg of subjects with lateral asymmetry recorded electromyographically while the subject walked on a treadmill when compared with similar recordings of the muscle action potentials of subjects with no lateral asymmetry of the pelvis.

Five specific hypotheses tested were:

1. There would be no difference in the action potentials of the biceps femoris of Group A (test group) recorded electromyographically when compared with the recordings of Group B (reference group).

2. There would be no difference in the action potentials of the semitendinosus of Group A recorded electromyographically when compared with the recordings of Group B.

3. There would be no difference in the action potentials of the sartorius of Group A recorded electromyographically when compared with the recordings of Group B.

4. There would be no difference in the action potentials of the gluteus maximus of Group A recorded electromyographically when compared with the recordings of Group B.

5. There would be no difference in the action potentials of the gluteus medius of Group A recorded electromyographically when compared with the recordings of Group B.

DEFINITIONS AND/OR EXPLANATIONS OF TERMS

The definitions and/or explanations which follow were offered to clarify the basic terminology as it is employed throughout the study.

Action Potential

The investigator accepted the description of deVries in explaining muscle action potential as the electrical change that accompanies the contraction of muscle tissue. This change can be recorded and measured electromyographically.[14]

Asymmetry

Asymmetry, according to Klein and Buckley, is bilateral imbalance at the pelvic level with a resulting inequality in leg length.[15] Not all asymmetry was considered to be at the pelvic level; however, since their paper dealt solely with the pelvic area they defined lateral asymmetry as occurring at the pelvic level. The state of asymmetry is not being identical on both sides of a central

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[14] Herbert deVries, Physiology of Exercise for Physical Education and Athletes (Dubuque, Iowa: William C. Brown Co., 1963), p. 22.

[15] Karl K. Klein and John C. Buckley, "Asymmetries of Growth in the Pelvis and Legs of Growing Children--A Preliminary Report," Journal of American Physical Medicine and Rehabilitation (July-August, 1966), p. 112.

line. The central line in the human body is the spinal column. If a person is symmetrical, the bones on either side of the spinal column will be on the same level as the bone structure on the other side. Therefore, a person with symmetry at the pelvic level will have the two iliac crests level with one another.

Electrodes

Electrodes pick up the action potentials every time a muscle contracts.[16] The electrodes utilized in the study were designed to be attached to the surface of the skin. The electrodes used are silver disc electrodes with a concave inner surface and a protective plastic covering. Two of these electrodes were used for each muscle studied.

Electromyograph

For the study, the definition of Basmajian was accepted. This definition stated that, "an electromyograph is a high gain amplifier with a preference or selectivity for frequencies in the range from about ten to several thousand cycles per second."[17]

The technique used is called "quantitative electromyography."[18] This involved the study of the amount of electrical activity present in a given muscle per unit time.

Electromyography

According to deVries, "the recording of muscle action potentials is called electromyography."[19] Basmajian states that, "electromyography

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[16]deVries, op. cit., p. 22.

[17]Basmajian, Muscles Alive, op. cit., p. 23.

[18]deVries, op. cit., p. 22.

[19]Ibid.

is unique in revealing what a muscle actually does at any moment during the various movements and postures."[20]

Lateral Asymmetry (Figure 1)

Lateral asymmetry, as used in the study, refers to asymmetry of the pelvic girdle. It is a rotation of the pelvis in the frontal plane about a sagittal-horizontal axis in such a manner that one iliac crest is lowered and the other is raised. The tilt is named in terms of the side which moves downward. A lateral tilt of the pelvis to the left demonstrates a tilt in which the left iliac crest is lower than the right.[21] For the purposes of the study lateral asymmetry was defined as a pelvic tilt in which one iliac crest was one half inch or more lower than the other.

Microvolts and Millivolts

Microvolts and millivolts are the units of measurement used to measure the action potentials of a muscle. A microvolt is a millionth of a volt and a millivolt is a thousandth of a volt.[22]

Motor Points

Motor points are areas on a muscle (some muscles have more than one) where the electrical potential of the muscle is the strongest. The motor point is the best place to innervate a muscle through external

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[20]Basmajian, Muscles Alive, op. cit., p. 22.

[21]Klein, op. cit., p. 116.

[22]Basmajian, "Electromyography," op. cit., pp. 10-11.

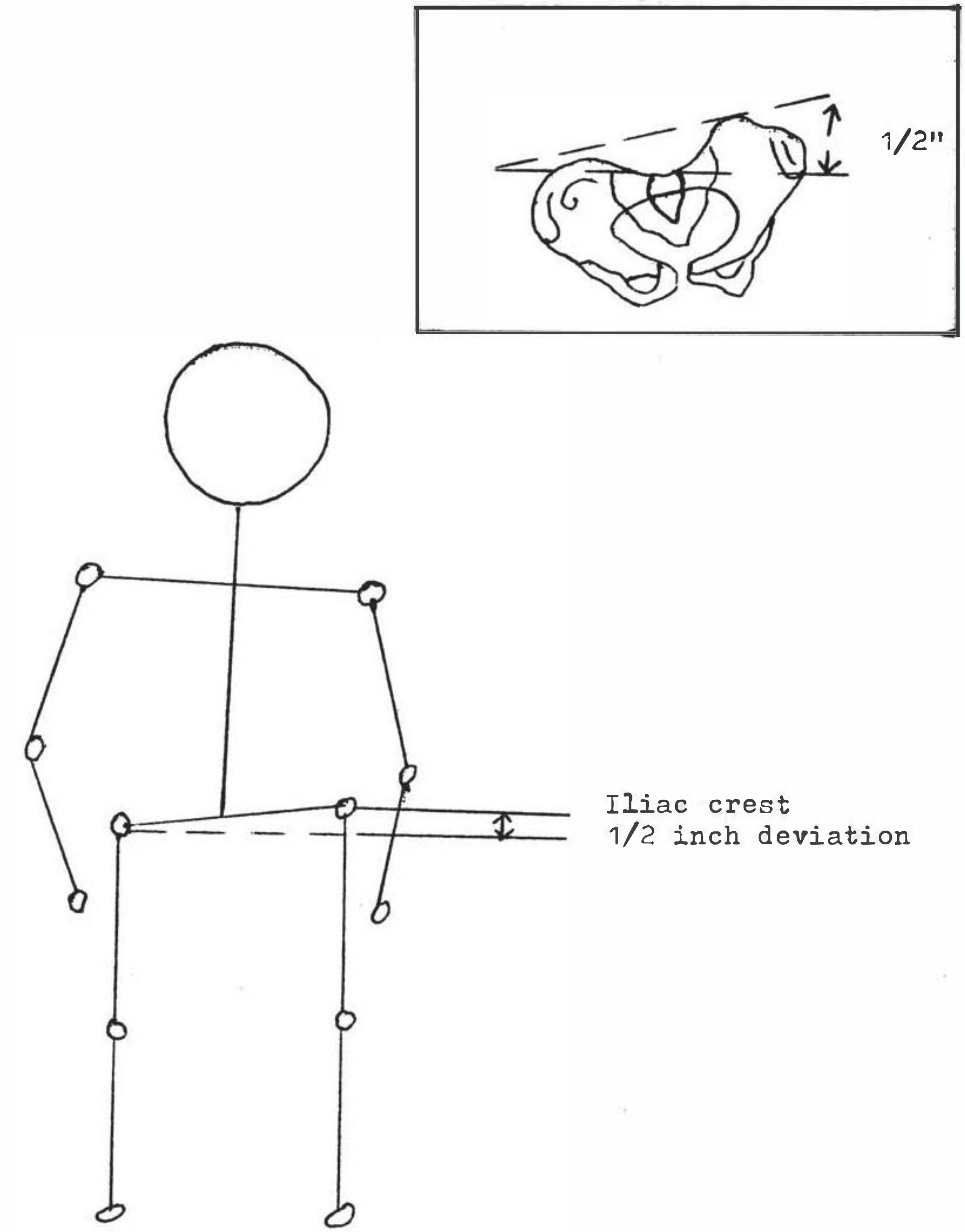

FIGURE 1

SCHEMATIC REPRESENTATION OF

LATERAL ASYMMETRY

electrical stimulation. It is also the recommended placement site for surface electrodes.[23]

Muscles to be Tapped for Electromyograms

The muscles studied in the investigation were: (1) biceps femoris (the two heads of which were not studied separately), (2) semitendinosus, (3) sartorius, (4) gluteus maximus, and (5) gluteus medius. These particular muscles were chosen because they are the superficial muscles of the upper leg and are therefore relatively easy to record electromyographically. These muscles are also the muscles that act on the hip joint during the walking motion.[24]

Normal Skeletal Structure

For the purposes of the study, normal skeletal structure was defined as a skeletal structure that was symmetrical, with the spine being the center line. This implies that the subject would not be suffering from such postural faults as scoliosis, lordosis, or pelvic tilt.

Phases of Walking

Close divided the walk into two phases--the stance phase and the swing phase. The stance phase of one leg begins when the heel of that leg touched the ground and ends when the toe of the same leg

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[23]Daniel P. Quiring and John H. Warfel, The Extremities (Philadelphia: Lea and Febiger, 1960), p. 10.

[24]Information collected from Wells, Basmajian, Close, Rasch and Burke, Joseph, Battye and Joseph, and MacConaill and Basmajian (see p. 48.).

pushes off from the ground. This latter movement is also the beginning of the swing phase. The swing phase of the same leg begins as the toe pushes off from the ground and ends when the heel of the same foot touches the ground.[25]

Basmajian agreed with Close on the phases of the walking cycle. He stated that the human gait is composed of two phases: (1) stance, beginning when the heel strikes the ground, and (2) swing, beginning with the toeing-off.[26]

Reference Group

For the study, Group B was the reference group. The five subjects who comprised the reference group did not have the condition defined as lateral asymmetry of the pelvis. It was believed that they demonstrated a normal pattern of muscle action (as defined by Basmajian and Close in the review of related literature). For this reason they were used as references for comparison with the electromyograms of the subjects with the condition defined as lateral asymmetry of the pelvis.

Walking on the Treadmill

For the purposes of the study, walking was defined as a heel-toe action walk. The walk was regulated by the use of a treadmill. The treadmill was set arbitrarily at three miles per hour and zero percent grade, the standard procedure at the Human Performance Laboratory at Eastern Illinois University, to ensure that all subjects walked at the same speed.

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[25] J. R. Close, Motor Function in the Lower Extremity: Analysis by Electronic Instrumentation (Springfield: Charles C. Thomas, Pub., 1964), p. 82.

[26] Basmajian, Muscles Alive, op. cit., p. 255.

ANATOMY OF THE MUSCLES STUDIED

The descriptions which follow are offered to clarify the location and the functions of the muscles studied in the investigation.

Biceps Femoris (Figure 2)

The biceps femoris, along with the semimembranosus and semitendinosus, forms the group of muscles known as the hamstrings. The muscle has two heads--a long head and a short head. The muscle is inserted on the head of the fibula and originates from the middle of the linea aspera and the upper part of the lateral supracondylar line.[27] Biceps femoris also acts on the knee joint as well as being a hip extensor.

> Electromyography reveals that in walking Semitendinosus and Biceps Femoris (short head) act when the foot is off the ground--they carry the weight of the leg; Semimembranosus and Biceps Femoris (long head) act when the foot is on the ground--they probably are concerned with extending the hip and so lifting the weight forward.
>
> The Biceps Femoris is alone responsible for the ability to rotate laterally at the flexed knee, but Semimembranosus and Semitendinosus are assisted by the Sartorius, the Gracilis, and the Popliteus in medial rotation of the flexed knee.[28]

Gluteus Maximus (Figure 3)

The gluteus maximus, one of the largest and thickest muscles in the body, is placed entirely behind the hip joint. The muscle originates from the mass of ligaments binding the posterior portion

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[27]J. V. Basmajian, Primary Anatomy (Baltimore: The Williams and Wilkins Co., 1966), p. 182.

[28]Ibid., p. 183.

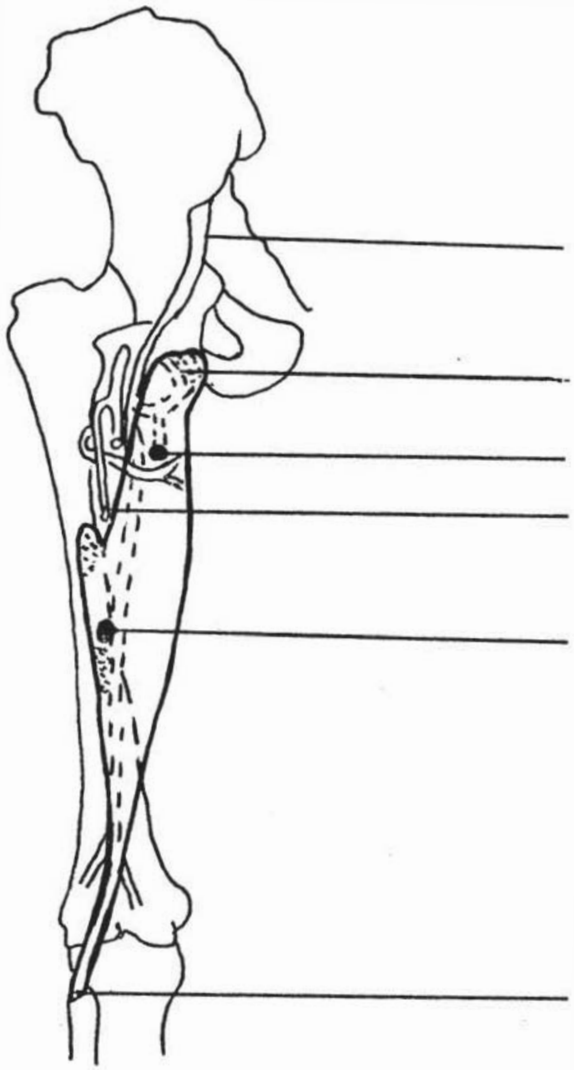

FIGURE 2

BICEPS FEMORIS

Daniel P. Quiring and John H. Warfel, The Extremities (Philadelphia: Lea and Febiger, 1960), p. 85

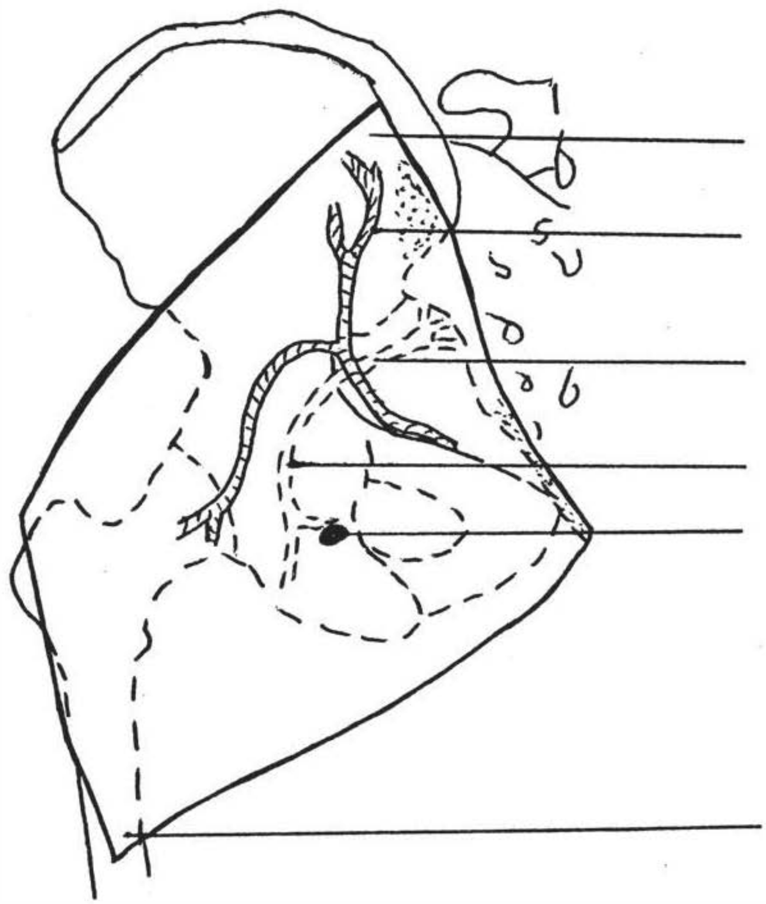

FIGURE 3

GLUTEUS MAXIMUS

Daniel P. Quiring and John Warfel, The Extremities (Philadelphia: Lea and Febiger, 1960), p. 75

of the sacro-iliac joint and from the sacro-tuberous ligament. It inserts into the ilio-tibial band. Gluteus maximus is used to extend the hip joint when the joint has to be extended with power.[29] It also outwardly rotates and abducts the thigh in the hip joint.[30]

Gluteus Medius (Figure 4)

The gluteus medius originates on the outer surface of the ilium but further forward than the gluteus maximus and inserts on the greater trochanter of the femur. The muscle abducts the thigh and rotates it medialwards. If when standing erect, the support of one limb is suddenly removed, the gluteus medius of the other side springs into action to prevent the pelvis from falling to the unsupported side. The muscle can be felt to harden and contract vigorously the instant the limb of the other side leaves the ground. It acts as a dynamic ligament, and the alternate action of the muscles of the two sides is responsible for maintaining the pelvic level in the act of walking.[31]

Sartorius (Figure 5)

The sartorius muscle is the longest muscle in the body, arising from the anterior superior spine of the ilium and inserting on the medial side of the knee by way of a tendon on the upper part of the tibia. Sartorius is considered as a weak flexor, abductor and lateral rotator of the hip.[32]

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[29]Ibid., p. 172.

[30]Erling Karlsson and Bengt Jonsson, "Function of the Gluteus Maximus Muscle," Acta Morphologica Neerlando-Scandinavica (1964-1966), VI, p. 168.

[31]Basmajian, Primary Anatomy, op. cit., p. 174.

[32]Ibid., p. 176.

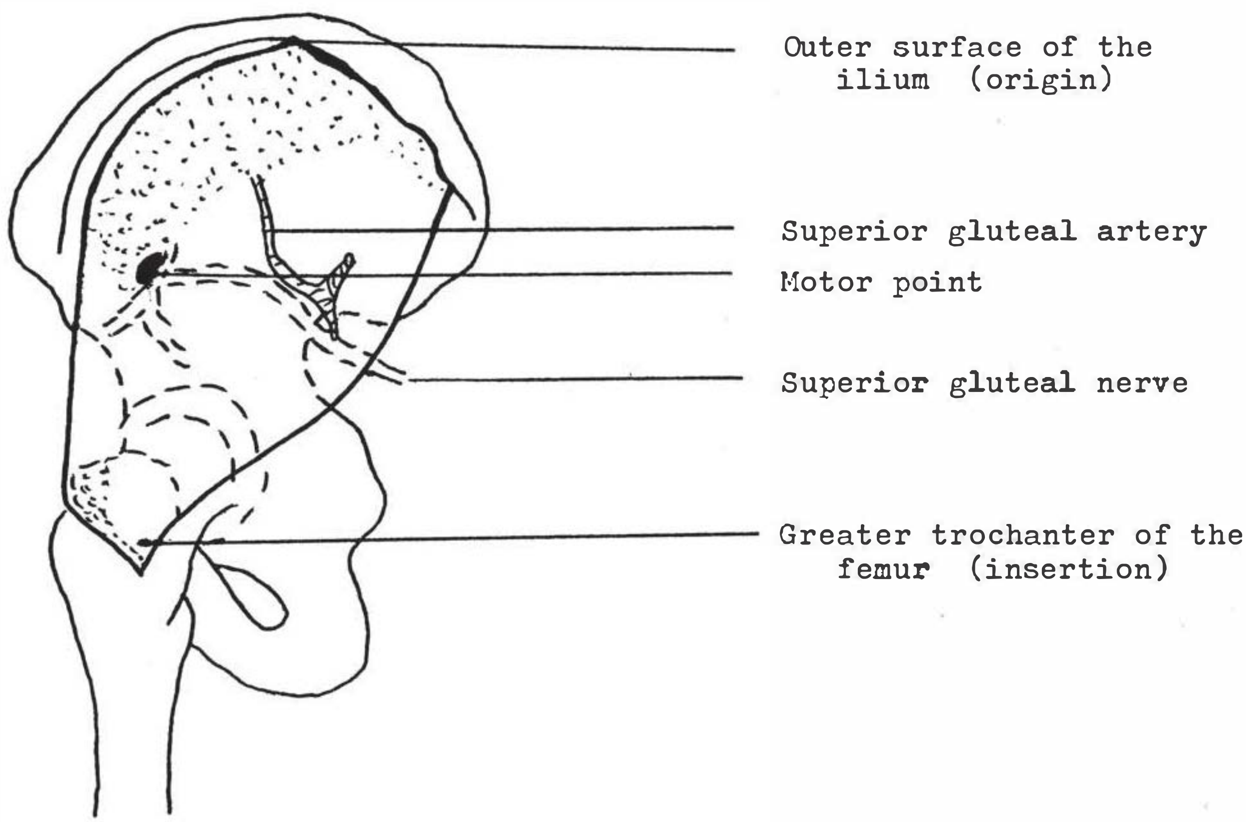

FIGURE 4

GLUTEUS MEDIUS

Daniel P. Quiring and John H. Warfel, The Extremities (Philadelphia: Lea and Febiger, 1960), p. 76

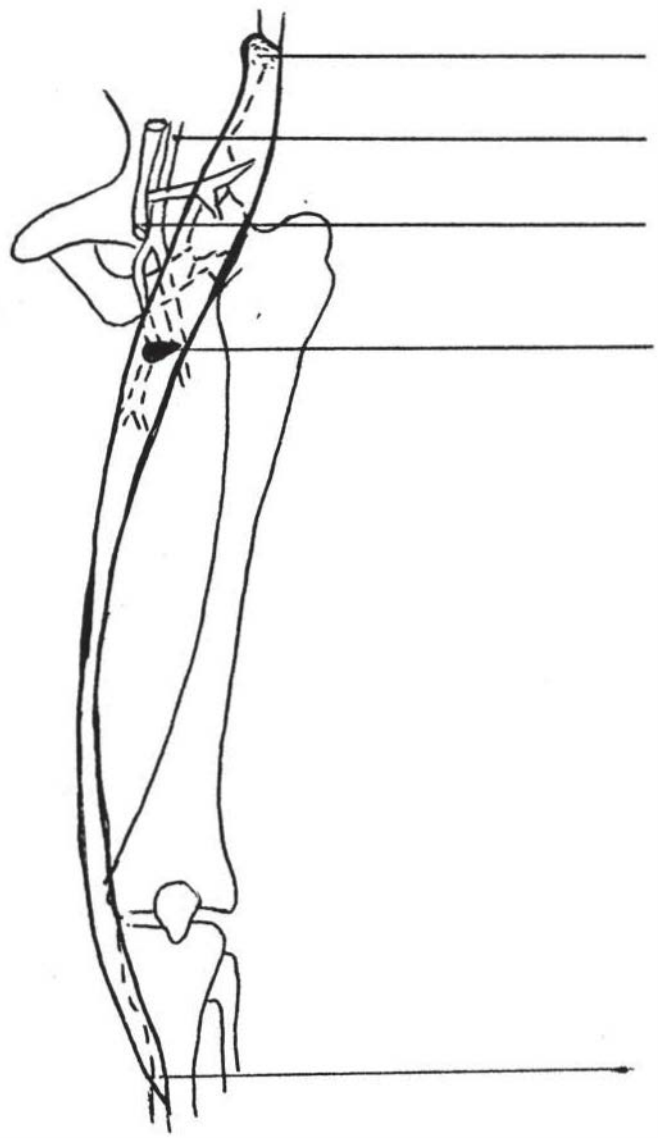

FIGURE 5

SARTORIUS

Daniel P. Quiring and John H. Warfel, The Extremities (Philadelphia: Lea and Febiger, 1960), p. 65

Semitendinosus (Figure 6)

This muscle is the third muscle to make up the group known as the hamstrings. It has the same origin and the same action as the biceps femoris and the semimembranosus; that is, it originates on the ischial tuberosity and it extends the hip as well as helping to take the weight of the partially flexed leg as the foot leaves the ground. This muscle inserts into the tibial shaft.[33]

DELIMITATIONS OF THE STUDY

The study was subjected to the following delimitations:

1. Five female subjects demonstrating the condition designated as lateral asymmetry of the pelvis and five reference subjects were utilized in the study. The age and body build of the subjects were not considered as factors affecting the outcome of the study. Anthropometric measurements are considered not to be an exact science. The technique used for determining the amount of lateral asymmetry relied on anthropometric-like measurements and, therefore, could not be considered to be an exact measurement. There was a margin of error present in palpating the iliac crests and marking the points on the surface of the skin. However, an exact measurement was not critical to the outcome of the study. The arbitrary measurement of a lateral asymmetry deviation of one half inch was utilized to ascertain that the test subjects did indeed have the condition defined as lateral asymmetry of the pelvis.

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[33]Ibid., p. 182.

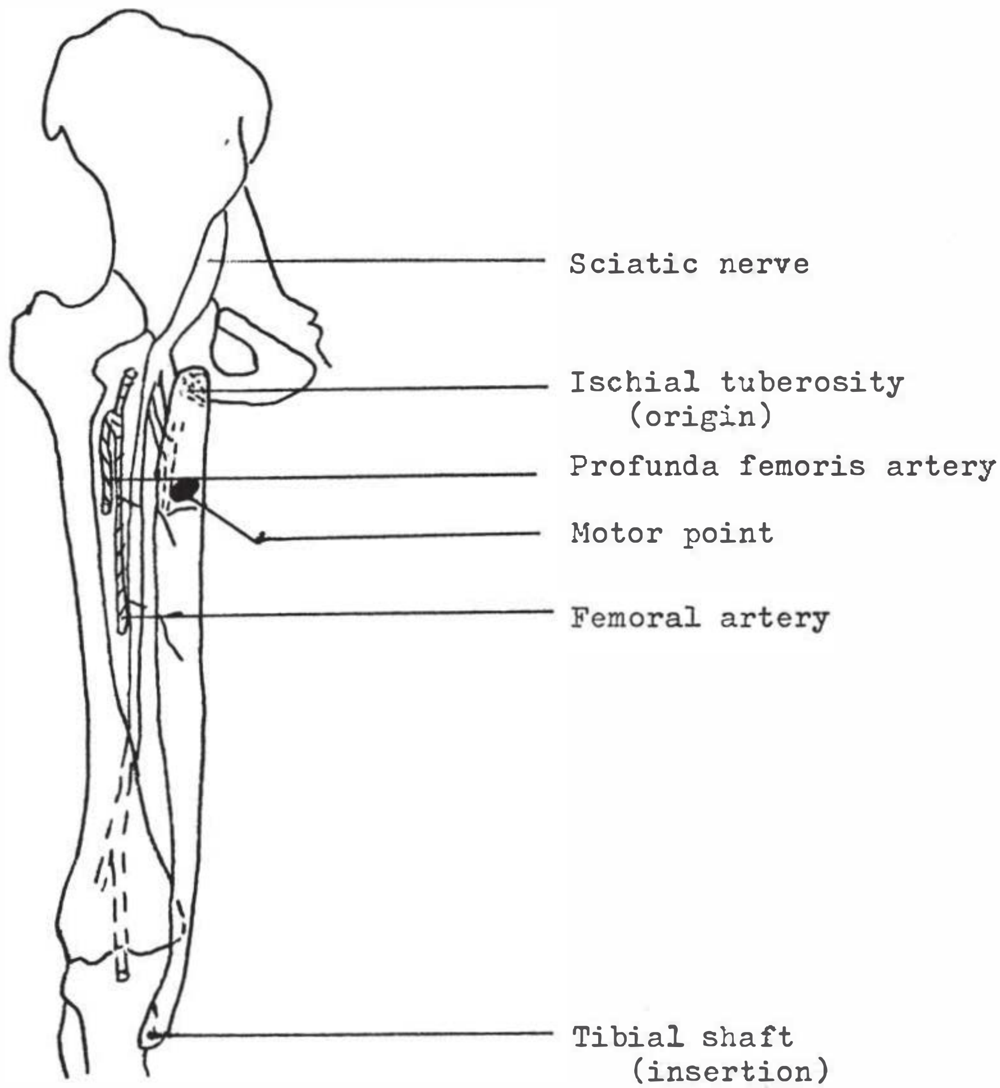

FIGURE 6

SEMITENDINOSUS

Daniel P. Quiring and John H. Warfel, The Extremities (Philadelphia: Lea and Febiger, 1960), p. 86

2. A four channel physiograph adapted for electromyography through the use of two high gain preamplifiers, products of Narco Bio-Systems Inc.,[34] was utilized. The use of the four channel physiograph limited the number of muscles that could be recorded for electromyograms at one time to two. The decision was made to record the action potentials for the electromyograms of the same muscle on each of the two limbs at one time.

3. Only the superficial muscles were studied. Specifically these muscles were: biceps femoris (the two heads were not studied separately), semitendinosus, sartorius, gluteus maximus, and gluteus medius. These muscles were studied in conjunction with the phases of walking as determined by Close.

4. Surface electrodes placed over the belly of the muscle, as close to the motor points as possible, were utilized for the collection of all data in the study. Surface electrodes are not selective; subsequently, it was possible that weak contractions of neighboring muscles were recorded. The great amount of fatty tissue found over the surface of the gluteal muscles in most female subjects also presented some difficulty.

5. All measurements taken on any one subject were completed in a single day.

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[34]Narco Bio Systems, 7651 Airport Blvd., Post Office Box 12511, Houston, Texas, 77017.

Chapter 2

REVIEW OF RELATED LITERATURE

The paper is an electromyographical study of the effects of lateral asymmetry on selected muscles in the upper leg employed in walking on a treadmill. The study necessitated a review of related literature in five areas: (1) lateral asymmetry, (2) postural studies with references to lateral asymmetry, (3) the muscles considered by selected authorities to be used during normal walking, (4) a brief history of electromyography and its uses, and finally, (5) electromyographic studies concerning walking and the effects of postural deviations on the muscles employed in walking.

A presentation of the data on lateral asymmetry was necessary to ascertain that authorities on postural deviations were aware of this postural fault and were in agreement on the definition as well as some of the causes and effects. The presentation of postural studies with reference to lateral asymmetry was included for similar reasons. It was also included to demonstrate that this area has not been neglected totally by physical educators. It was necessary to review the works of the anatomical and kinesiological authorities in order to determine which muscles they considered to be the muscles employed during walking. The last area in the chapter deals with the investigations concerning postural deviations and their possible effects on the muscles used in normal walking.

LATERAL ASYMMETRY

The term lateral asymmetry was first encountered in the works of Klein and Buckley.[35] Their definition was accepted and used for the purposes of the study. The definition of Klein and Buckley stated that lateral asymmetry, as used in their study, referred to asymmetry at the pelvic level. It is a rotation of the pelvis in the frontal plane about a sagittal-horizontal axis in such a manner that one iliac crest is lowered and the other is raised. The tilt is named in terms of the side which moves downward. A lateral tilt of the pelvis to the left demonstrates a tilt in which the left iliac crest is lower than the right crest.[36]

According to Klein and Buckley, lateral asymmetry of the pelvis exists in a high percentage of the population.[37] Their study involved the effect of heel-lifting procedure on a select group of elementary school students who demonstrated idiopathic scoliosis and tilting of the pelvic girdle and curve to the short leg side with the low shoulder to the high hip side. Through this study they attempted to demonstrate the influence of the heel lift to level the pelvis, balance the spine, and influence the development of bilateral posture balance. The investigators learned that by raising the short leg (by placing a metal insert in the shoe to raise the leg to the difference between the length of the two legs) they produced symmetry of the pelvis.

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[35]Karl K. Klein and John C. Buckley, "Asymmetries of Growth in the Pelvis and Legs of Growing Children--A Preliminary Report," Journal of American Physical Medicine and Rehabilitation (July-August, 1966), p. 112.

[36]Ibid.

[37]Ibid.

> The theory behind the basic hypothesis is that the balancing of the leg length would change the standing, walking, and movement patterns from an asymmetrical to symmetrical position, thus creating an equity of time spent on each leg during ambulatory time.[38]

Klein also related lateral asymmetry of the pelvis to low back stress in the adult.

Kelly agreed with Buckley and Klein that there are very few people who do not demonstrate some slight degree of asymmetry. Kelly maintained that asymmetry could occur in any part of the body. The ideal body posture includes symmetrical shoulders and hips, straight spine, and equal contours in the waistline. She states that slight differences were of little importance; however, a more serious degree of asymmetry could result in curvatures of the spinal column.[39] She also states that lateral asymmetry may be caused by trunk muscle insufficiency or by some asymmetrical bone development outside the spine, such as a short leg or pelvic equality.[40]

Lowman and Young[41] too were aware of lateral asymmetry of the pelvis and the effects it could have on any individual with this condition. It must be remembered that Lowman and Young, as well as Kelly, were referring to people with a pronounced postural deviation. Lowman and Young maintain that

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[38]Ibid., p. 114.

[39]Ellen Davis Kelly, Adapted and Corrective Physical Education (New York: The Ronald Press Co., 1965), p. 110.

[40]Ibid., p. 111.

[41]Charles Leroy Lowman and Carl Haven Young, Postural Fitness, Significance and Variance (Philadelphia: Lea and Febiger, 1960), p. 120.

> . . . it can be appreciated that any malalignment in this area (pelvis) can be potential troublemakers. Particularly since the heaviest of the body muscle masses are attached to the pelvis, the force of these muscles acting in the presence of postural faults accounts for many wear and tear symptoms in later life.[42]

Lowman and Young also state that a pelvic tilt is a fairly common deviation and occurs in about fifty percent of all persons. They further maintain that the tilt could be lateral, or forward, or backward.

They attribute the pelvic tilt to the following possible causes:

1. actual intrinsic differences in leg lengths;
2. unilateral arch depression;
3. unilateral knockknee, in which the difference of angulation of the knee joint tends to lower one side of the pelvis;
4. differences in the angulation of the necks of the femora with the shafts;
5. variations of size, shape or position of the component parts of the pelvic bones or innominate bones;
6. dissimilarities in size, shape and position of the two sides of the sacrum.[43]

Cyriax states, furthermore, that the relation of the anterior superior spine to the upper margin of the symphysis pubis, in normal subjects when viewed laterally should be in the same vertical plane. According to Cyriax, every half inch of deviation of the anterior

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[42]Ibid.

[43]Ibid., p. 124.

superior spine from this plane meant a corresponding alteration in the pelvic tilt of about nine degrees.[44]

Pelvic tilt is not necessarily connected with any curvature of the spine. As proof, the description of scoliosis by Clarke and Clarke is offered.

> In scoliosis, the shoulders tend to maintain their normal right angle with the upper thoracic spine, so uneveness in the shoulder region results; one shoulder, therefore, will be lower than the other. Some rotation of the spine also occurs, causing the posterior aspect of the attached ribs to become prominent on the side of the curve's convexity and the vertebral border of the corresponding scapula to pull away from the ribs. Unless the legs are of uneven length, the hips will be level; however, the iliac crest on one side will be more prominent than the other, due to the lateral sagging in the lumbar region.[45]

Meuller and Christaldi write that lateral pelvic tilt occurs when more weight is borne on one leg than the other. This happens, particularly, in the standing position when one knee is bent and the other is straight. Lateral tilt is also present in cases of a short leg.[46]

It is Meuller and Christaldi who point out a link between pelvic tilt and posture. More specifically, they state that lateral asymmetry has an effect on posture.

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[44]Edgar F. Cyriax, "On the Anterior-Posterior Tilt of the Pelvis; Its Variations and Their Clinical Significance in Children," British Journal of Child Diseases (Volume 24, 1924), p. 280.

[45]H. Harrison Clarke and David H. Clarke, Developmental and Adapted Physical Education (Englewood Cliffs, New Jersey: Prentice-Hall, 1963), p. 200.

[46]Grover W. Meuller and Josephine Christaldi, A Practical Program of Remedial Physical Education (Philadelphia: Lea and Febiger, 1966), p. 65.

The state of one's posture, whether efficient or faulty, is dependent primarily upon the tone of the antagonistic muscles which are responsible for maintaining well-balanced positions. When the body segments are correctly aligned, they are capable of exercising the maximum freedom of movement as well as the most efficient ease of organic function.[47]

The pelvis may well be called the "keystone" of good posture because of its basic importance in maintaining proper alignment of the trunk. In the normal standing position, the pelvis is inclined slightly forward in varying degrees.[48]

POSTURAL STUDIES WITH REFERENCES TO LATERAL ASYMMETRIES

Postural studies were most prevalent in the 1950's. Many of these studies concerned curvatures of the spine--the causes, effects, and remedial methods through physical education. Few studies concentrated solely on lateral asymmetry of the pelvis. Lateral asymmetry was considered when the investigators were concerned with postural deviations in all areas of the body.

The fact that postural deviations caused an inefficiency in motor function was not a disputed one. According to Davies some physical educators assumed that postural divergencies may inhibit or prevent a child from participating successfully. It has often been said that balanced posture enables one to have efficient movement patterns. If the body is out of alignment or is asymmetrical, a person is not expected to have efficient movement patterns. The unbalanced or asymmetrical posture may be the result of psychological, physical, or psychosomatic difficulties. Regardless of the reason, many people feel that movement is affected by postures, and that

[47]Ibid., p. 64.

[48]Ibid., p. 65.

postures affect movement. Davies continues to say that the amount of influence postures have on movement depends upon many factors, such as the type and severity of the deviation as well as the type and duration of movement.[49]

Davies conducted a study of one hundred women students from the University of California at Los Angeles. The subjects were given a subjective postural screening by three experts in the area of posture. The posture was studied while the student was walking or bending forward or sideward. The subjects were then given the Scott Motor Ability Battery of tests. Correlations were computed between selected postural divergencies found in the subjects and their motor ability, using the mean of the divergencies marked by three expert judges and the motor ability of the subject. The correlation coefficients obtained from the hundred subjects indicated: (1) a low negative relationship between the mean of the combined ratings of the judges of the subjects of gait divergencies; (2) a low positive relationship between the mean of the combined ratings of the judges of over-all postural divergencies and motor ability; (3) a low positive relationship between the mean of the combined ratings of the judges of decreased lumbar curve and motor ability; (4) a low positive relationship between the mean of the combined ratings of the judges of restricted flexibility and motor ability. Davies concludes that it appeared that there was little or no relationship between postural divergencies as measured by the ratings of the

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[49]Evelyn A. Davies, "Relationship Between Selected Postural Divergencies and Motor Ability," The Research Quarterly (Volume 28, March 1957), p. 1.

judges and motor ability for the subjects used in the study.[50]

The investigation conducted by Davies bears some relationship to the present study in that Davies considered postural divergencies and their effect on walking. She states that postural divergencies have little relationship to gait divergencies. It was one of the concerns of the present investigation to attempt to demonstrate that the postural divergency of lateral asymmetry of the pelvis has a relationship to gait divergencies.

Heulster agreed with Davies that postural divergencies affected the functional efficiency of the body. She qualified this by the statement, "there is a lack of agreement, however, in desirable standards of structural alignment for satisfactory functioning."[51]

The paper, "The Relationship Between Bilateral Contour Asymmetry in the Human Body in Standing and Walking," by Heulster was based on certain fundamental assumptions: (1) the skeletal structure is the framework supporting the weight of the body and it also acts as a lever system in order for the muscles to be able to move that body; (2) skeletal alignment and accompanying muscle action are interrelated and interdependent no matter what position the body is in or what movement it may be performing; (3) bilateral asymmetry tends to occur in skeletal alignment and in body contour of normal individuals in the standing position, it will tend to be reflected in bilateral movements

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[50]Ibid., p. 4.

[51]Laura J. Heulster, "The Relationship Between Bilateral Contour Asymmetry in the Human Body in Standing and Walking," The Research Quarterly (Volume 24, March, 1953), p. 44.

in walking; (4) when asymmetry occurs in one portion of the body, it is apt to occur in other portions of the body as well; (5) a vertical axis to divide the body into lateral halves was set at the center of the sacral table where the weight of the spinal column and its appended structures is transferred to the left and right sides of the pelvis.[52]

The problem presented in the study by Heulster was to determine patterns of bilateral contour asymmetry in standing and in walking when body weight was supported alternately on each limb, and the relationship among these patterns.[53] She concluded that: (1) in standing and in walking, reliability of asymmetry tends to be greatest at the level of the upper sacrum. In alternate limb support in walking, reliability tends to be greater when body weight is supported by the limb which is closer to the control vertical axis in standing; (2) two of the patterns in walking show complete correspondence to two of the patterns in standing, both in their asymmetry and in their movement factors. A third pattern in walking involves the knee and the foot, as it does in standing, but the pattern in walking is found in the swinging limb only and its movement factor is different from that of the pattern in standing. The fourth pattern occurs only in standing; (3) in standing and walking, a significant relationship tends to occur between the two corresponding patterns whose asymmetries and movement factors are in complete agreement.[54]

Frost[55] compiled a paper on a different kind of asymmetry. Her paper was concerned with whether variations in the anteroposterior curves

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[52]Ibid. [53]Ibid., p. 46. [54]Ibid., p. 54.

[55]Loraine Frost, "The Relationship Between Variations in the Antero-Posterior Curves of the Spine and Scoliosis," The Research Quarterly (Volume 1, 1930), p. 29.

accompany scoliosis, and if so, whether the kinds of variations were correlated with respect to type or location. Each subject was photographed from the side, back, and with the spine of the subject flexed. The photographs were then projected to life size, and tracings made of both lateral and anteroposterior curves with the same fixed point for the seventh cervical vertebra. The final estimation of variations in the anteroposterior curves was made on the basis of separate gradings of four persons. From this study Frost concluded that a change from the normal in one plane with a consequent decrease in the mechanical efficiency of the spine, is accompanied or followed by a corresponding change in the other plane, that there was no positive correlation as to the types of variations in the anteroposterior curves with which scoliosis, in general, or specific types of scoliosis most frequently occur, and that there was no positive correlation between the exact location of the variations in the anteroposterior curves and that of either the lateral deviation, or rotation, although they were found to coincide, with respect to at least one of these factors in scoliosis, in fifty percent of the cases studied.[56]

The purpose of the study by Maple[57] was to discover what relation there may be between age and posture and thus to determine whether or not the standard of posture should be differentiated according to age. Maple was concerned more with the posture of children rather

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[56]Ibid., p. 30.

[57]Katharine N. Maple, "Chronological Variations in the Posture of Children Ages One to Seven and Ten to Thirteen," The Research Quarterly (Volume 1, 1930), p. 30.

than that of adults. The study was confined to the variations in the anterior-posterior relationship of the parts of the body, as observed in the children between the ages of one and fourteen. Four areas were measured with a protractor and a plumb line. These four areas were: (1) the position of the head and inclination forward of the cervical spine; (2) the tilt and position of the scapula; (3) the angle of the sacrum, which is at once an indication of the inclination of the pelvis and the acuteness of the lumbar curve; and (4) the weight distribution, particularly as it affects the anterior-posterior relation between the pelvic girdle and the shoulder girdle. These areas were measured with a protractor and a plumb line. All measurements were taken from the left profile. Photographs were then taken and measurements made from these photographs. The conclusions arrived at by the investigator were: (1) the head is not held erect until the sixth or seventh year; (2) the scapula are extremely tilted at the ages of four and five and have not reached a sufficiently posterior position to lie flat upon the back until the ages of ten to thirteen; and (3) this study bore out the statement that the infant is more erect than the child.

The study by Spindler[58] was one of multiple purpose. Yet, the study, like the others, was also concerned with physical defects and their connection with functional disorders. The purposes of this study were: (1) to show the prevalence of physical defects during adolescence and to present statistical evidence to support the common observations

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[58]Evelyn B. Spindler, "Prevalence of and Correlations Between Physical Defects and Their Coincidence with Functional Disorders," The Research Quarterly (Volume 2, 1931), p. 36.

and opinions of physiotherapists and of directors who work in the field of Corrective Physical Education; (2) to summarize these statistics in groups so as to make obvious to high school principals and superintendents the advisability and real necessity of having adequate physical examinations, and of backing up such examinations with real remedial work of both group and individual types, apart from and in addition to the broader athletic and recreational program; (3) to point out and to emphasize the important changes in body structure and functional disorders that can be due to postural defects; and (4) to correlate and bring together the findings of this within and of others in similar studies made in theses at the University of Wisconsin.[59]

The plumb line was used to help measure the anterior deviation, while lateral deviations were measured from the straight line of the spine. A grade was assigned according to the number of degrees from the normal that the deviation occurred. All freshmen women entering the University of Wisconsin were examined and received a follow-up exam the next spring. The following is a list of conclusions drawn by Spindler: (1) remedial and corrective work are necessary; (2) physical examination is essential to diagnosis; (3) asymmetrical sport emphasis tends to create lateral curves; (4) the problem of correctives belongs in the secondary school; (5) we must renew and increase postural emphasis in education; (6) the greater the degree of defect in any one aspect or group, the greater the percentage of association defects; (7) special classes for individual needs are necessary; (8) there is a definite progression of difficulties; and (9) styles and fads which

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[59]Ibid., p. 33.

affect posture must be combatted.[60] Spindler arrived at these conclusions after she learned that anatomical deviations were often accompanied by physiological problems such as strain or pressure on muscles, cramped lungs, pressed upon nerve trunks, and cramped pelvic organs by the changed angle of the pelvis and consequent weight of the abdominal viscera pressing downward on them.[61] Spindler learned further that the cases of serious postural deviations were diminishing with the years and with the emphasis of society and schools on postural education and remedial and adapted physical education. Physical education, in many cases, improved the posture and helped to alleviate the deviation. Lateral deviations were not improved, however. Certain sport activities, such as swimming, were found to make postural deviations worse. (This was the case at the University of Wisconsin where the asymmetrical sidestroke was emphasized.) Other sports, such as archery, were found to help correct postural deviations.[62]

MUSCLES CONSIDERED BY SELECTED AUTHORITIES TO BE USED DURING NORMAL WALKING

In order to help determine whether or not lateral asymmetry of the pelvis affected the muscles used in walking, it was necessary to ascertain which muscles were employed during the walking action. Writings of several authorities on anatomy and kinesiology were consulted.

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[60]Ibid., pp. 54-56.

[61]Ibid., p. 40.

[62]Ibid.

According to Basmajian[63] hamstrings worked at the peak of their activity when the heel struck the ground. The quadriceps acted as the body was carried forward over the limb. Before and during the push-off with the toe, quadriceps, and sometimes hamstrings, reached another but smaller peak of activity.

In his electromyographical studies of normal walking, Close[64] found that: biceps femoris (short head) was active during the ending of the stance phase and beginning of the swing phase, semitendinosus was active during the middle of and end of the swing phase, and semimembranosus was active during all phases of the walking cycle. According to the deflection of the amplitude measured in millivolts on the electromyograms, semimembranosus and semitendinousus were the prime movers during the stance phase.

Wells[65] stated that the tensor fasciae latae, sartorius, pectineus, and iliopsoas were active during the first part of the swing phase, while rectus femoris contracted slightly at the same time. The hamstrings (long head of biceps femoris) contracted with moderate activity during the end of the swing phase. The adductors longus, magnus, and brevis, contracted slightly after the middle swing phase. During the middle of the swing phase, biceps femoris, semimembranosus,

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[63] J. V. Basmajian, Muscles Alive: Their Functions Revealed by Electromyography (Baltimore: The Williams and Wilkins Co., 1962), p. 255.

[64] J. R. Close, Motor nction in the Lower Extremity: Analysis by Electronic Instrumentation (Springfield: Charles C. Thomas, 1964), p. 79.

[65] Katharine Wells, Kinesiology: The Scientific Basis of Human Motion (Philadelphia: W. B. Saunders Co., 1967), pp. 415-416.

and semitendinosus contracted. The quadriceps contracted slightly at the end of the swing phase. During the first part of the stance phase all three gluteal muscles contracted. The adductors magnus and longus contracted moderately at the beginning of the stance phase.

Rasch and Burke[66] stated that shortly after the heel struck the ground the gluteus maximus began to contract. The swing phase was carried out by the hip flexors. The hamstrings contracted at the end of the swing phase.

In his electromyographical study of walking, Liberson[67] found that contraction of the triceps surae was followed by that of gluteus maximus of the opposite side. Dorsiflexion of the foot began at the time of maximum acceleration of the lower leg. Extension of the knee began at the time of maximum velocity of the leg.

In a brief preliminary report, Joseph[68] described his findings of the telemetered electromyograms from a number of muscles used in gait. In the swing phase, the hamstrings were inactive (even though knee flexion occurred) and the tibialis anterior was also inactive, but only for a brief period. In the supporting phase, activity occurred early in the calf muscles, hamstrings and gluteus maximus but ceased toward the end. Two periods of inactivity were found in the sacrospinalis: one during the swinging and one during the supporting phase.

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[66]Philip J. Rasch and Roger K. Burke, Kinesiology and Applied Anatomy (Philadelphia: Lea and Febiger, 1967), p. 381.

[67]W. T. Liberson, "Biomechanics of Gait, A Method of Study," Archives of Physical Medicine (Volume 46, 1965), pp. 37-48.

[68]J. Joseph and A. Nightingale, "Electromyography of Muscles of Posture and Gait in Man," (abstract) Bulletin of American Association of Electromyography and Electrodiagnosis (Volume 4, 1966), pp. 125-135.

Battye and Joseph[69] concluded from their study that quadriceps femoris contracted as extension of the knee was being completed, not during the earlier part of extension when the action was probably a passive swing. Quadriceps continued to act during the early part of the supporting phase (when the knee was flexed and the center of gravity fell behind it). Quadriceps activity occurred at the end of the supporting phase to fix the knee in extension, probably counteracting the tendency toward flexion imparted by the gastrocnemius. The hamstrings contracted at the end of flexion and during early extension of the thigh before the heel was on the ground and to assist the movement of the body over the supporting limb. In some persons, the hamstrings also contracted a second time in the cycle during the end of the supporting phase: this may have prevented hip flexion. Gluteus maximus and minimus were active during the supporting phase; however, some subjects showed activity at the end of the swing and at the beginning of the supporting phase.

MacConaill and Basmajian[70] found that the gluteus maximus was active when the center of gravity of the whole body was grossly shifted, as in the case of walking. In positions where "one leg sustains most of the weight, the ipsilateral muscle is active in its upper part; apparently this was to prevent a dropping of the opposite side."[71] The semitendinosus flexed the knee during the swing phase of walking (on a

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[69] C. K. Battye and J. Joseph, "An Investigation by Telemetering of the Activity of Some Muscles in Walking," Medical and Biological Engineering (Volume 4, 1966), pp. 125-135.

[70] M. A. MacConaill and J. V. Basmajian, Muscles and Movements, A Basis for Human Kinesiology (Baltimore: The Williams and Wilkins Co., 1969), pp. 237-240.

[71] Ibid., p. 237.

treadmill) while semimembranosus acted mostly while the foot was on the ground. Although both heads of biceps femoris acted at the same time during a free-moving test of flexion, the short head acted during the swing phase of walking while the long head acted as a stabilizer when the foot was on the ground. The hamstrings were usually active during the transition from the swing phase to the stance phase.

A BRIEF HISTORY OF ELECTROMYOGRAPHY AND ITS USES

The insertion of electrodes in muscles, or application of electrodes on the surface of the skin over the belly of the muscles, through the recording of the electromyogram permits better insight into the quantitative aspects of movements than does mere inspection. This section of the chapter was offered to provide understanding of the preceding statement by relating how electromyography evolved and what its present-day significance is.

The concept of electromyography began in the eighteenth century with Galvani and his experiments with electrical stimulation of muscles. It was Galvani who discovered the fact that a muscle can be stimulated to contract by an electrical current. He also learned that the contracting muscle emits a small electrical charge. Volta, too, applied his efforts to the same concepts.[72]

The first true experiments, and experiments they were, in the field of electromyography were conducted by Adrain and Bronk[73]. Their

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[72] J. V. Basmajian, "Electromyography," University of Toronto Medical Journal, Volume 30 (Toronto: University of Toronto Press, 1952), p. 11.

[73] E. D. Adrian and D. W. Bronk, "The Discharges of Impulses in Motor-nerve Fibres," Journal of Physiology (Volume 67, 1929), p. 119.

first works concerned the characteristics of impulses in motor-nerve fibres and how they applied to the moving muscle. The first needle electrodes resulted from their efforts. With the needle electrodes they were able to pick up the electrical changes in individual motor units as they contracted.

Other investigators of human motion became interested in this new technique and applied it to their studies. These first studies were conducted by the medical sciences and were primarily concerned with clinical problems. An example of this type of study is the one conducted in 1944 by Weddell, Feinstein, and Pattle[74] at Oxford on neuromuscular dysfunctions.

About the same time as Weddell and his group were working at Oxford, Jasper[75] was conducting investigations on nerve lesions at the Montreal Neurological Institute. Jasper and his aides developed the unipolar needle which soon replaced all other electrodes in subsequent investigations.

Scandinavian investigators entered the scene and produced many a first rate study of muscular activity. The most noted of the Scandinavian investigators were Buchthal, Kugelberg, and Clemmensen.

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[74] G. Weddell, B. Feinstein, and R. E. Pattle, "The Electrical Activity of Voluntary Muscle in Man Under Normal and Pathological Conditions," Brain (Volume 67, 1944), p. 188. (Quote taken from Basmajian, Muscles Alive, p. 11.)

[75] H. H. Jasper and G. Ballem, "Unipolar Electromyograms of Normal and Denervated Human Muscle," Journal of Neurophysiology, (Volume 12, 1949), p. 231. (Quote taken from Basmajian, Muscles Alive, p. 11.)

The study by Buchthal concerned the analyzing of muscle action potentials as a diagnostic aid in neuromuscular disorders.[76]

The first studies employing electromyographical techniques were not readily accepted. This was due to inaccuracies incurred by unreliable apparatus. However, the demands of war on technology provided a remedy. New and improved equipment produced a renewed interest which was confined at first to neurologists and physical therapists. Physiologists and anatomists quickly entered the field. Kinesiologists and physical educators were the next professional groups to produce studies relying heavily on electromyography.[77]

Electromyography revolutionized anatomical investigations. Through electromyography the specific actions of many muscles during every type of movement was revealed. Palpation and observation could not hope to equal the results obtained through electromyography. Inman, Saunders, and Abbott published papers on the functions of the abductor muscles,[78] and functions of the muscles of the shoulder joints[79]

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[76]F. Buchthal and P. Pinelli, "Analysis of Muscle Action Potentials as a Diagnostic Aid in Neuromuscular Disorders," Acta Morphologica Neerlando Scandinavica (supplement) (Volume 226, 1952) pp. 315-327.

[77]Basmajian, Muscles Alive, op. cit., pp. 10-11.

[78]V. T. Inman, "Functional Aspects of the Abductor Muscles of the Hip," Journal of Bone and Joint Surgery (Volume 29, 1947), pp. 607-619.

[79]V. T. Inman, J. B. Saunders, and L. C. Abbott, "Observations of the Function of the Shoulder Joint," Journal of Bone and Joint Surgery (Volume 26, 1944), pp. 1-30.

among others. Basmajian authored several books[80,81] using the knowledge gained through his electromyographical investigations.

The physical educators took the study of the functions of the muscles one step further. Many of them conducted investigations of the function of specific muscles during specific sports skills. An example of this type of investigation is the study of Broer and Houtz.[82]

Of necessity, electromyographical investigations fall into two categories: clinical and experimental. Clinical electromyography consists of investigating the changes that occur with various motor-nerve lesions, primary and secondary muscle dysfunctions, and the compressions of the spinal cord and nerve roots. Electromyography is also used in diagnosis since certain muscular dysfunctions have characteristic patterns.[83]

Experimental electromyography is conducted by physiologists, anatomists, physical educators, and kinesiologists. The type of investigations they are interested in is typified by Inman, Saunders, and Abbott, Basmajian, and Broer. Electromyography makes possible the following study or techniques:

a. The timing of muscular activity during such actions as walking (phasic activity).

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[80] J. V. Basmajian, Primary Anatomy (Baltimore: The Williams and Wilkins Co., 1964).

[81] J. V. Basmajian, Muscles Alive, Their Function Revealed by Electromyography (Baltimore: The Williams and Wilkins Co., 1967).

[82] Marion Ruth Broer and Sara Jane Houtz, Patterns of Muscular Activity in Selected Sports Skills: An Electromyographic Study (Springfield: Charles C. Thomas, 1967).

[83] Basmajian, "Electromyography," op. cit., p. 12.

b. The analyses of voluntary contraction enabling one to ascertain the relative importance of each muscle as it makes its contribution to various motions about joint systems.
c. Multichannel equipment makes possible an excellent display of reciprocal activity.
d. Studies of the patterns of action potential oscillograms in normal and pathological conditions.[84]

The minimum equipment necessary for electromyography includes electrodes, a preamplifier, an amplifier, a calibrator, and recording apparatus. The electrical potential developed in the muscle is so small that it must be amplified twice before it can be displayed. The electrode picks up the muscle potential and leads it through conducting wires to a preamplifier and from there to an amplifier, from which the magnified potential is led to a conversion device for permanent recording. The potential may be translated into a visual display by an oscilloscope or into sound by a loud-speaker, or it may be fed into a magnetic tape.[85]

ELECTROMYOGRAPHIC STUDIES CONCERNING WALKING AND THE EFFECTS OF POSTURAL DEVIATIONS ON THE MUSCLES EMPLOYED IN WALKING

Of all the electromyography done in recent years, studies on locomotion gave the greatest promise of practical application. "Locomotion and gait are not synonymous, but unfortunately no electromyographical research has gone beyond simple walking."[86]

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[84]Close, op. cit., p. 7.

[85]Arthur A. Rodriquez and Y. T. Oesta, "Fundamentals of Electromyography," Electrodiagnosis and Electromyography ed. Sidney Licht (New Haven, Conn.: Elizabeth Licht Pub., 1961), p. 287.

[86]Basmajian, Muscles Alive, op. cit., p. 253.

Through their investigation of the muscles employed in walking, Saunders, Inman and Eberhart[87] were able to define the six major determinants of human gait as: (1) pelvic rotation, (2) pelvic tilt, (3) knee flexion, (4) hip flexion, (5) knee and ankle interaction, and (6) lateral pelvic displacement. When a person lost one of these determinants, according to Saunders, et al., compensation was reasonably effective. Loss of the determinant at the knee proved to be the most costly. Loss of two determinants made effective compensation impossible.

Close[88] conducted an extensive investigation of the electromyographical patterns of walking--both normal and pathological. He compared the patterns of walking of normal subjects with the patterns of subjects with various pathological conditions. Close stated that he employed this method since "the normal subject is our only beginning reference."[89]

One of the first subjects he studied demonstrated paralysis. He concluded that muscular contraction timing during locomotion differed from the normal in the paralytic patient. The paralytic used his remaining musculature in a different fashion from the normal individual. The degree of variation from the normal pattern depended on the extent of paralysis. An example was the iliopsoas muscle which was found to be completely inactive in the normal subject during walking. The paralytic made considerable use of the iliopsoas during walking.[90]

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[87] J. B. Saunders, V. T. Inman, and H. D. Eberhart, "The Major Determinants in Normal and Pathological Gait," Journal of Bone and Joint Surgery (Volume 35-A, 1953), pp. 543-558.

[88] Close, op. cit. [89] Ibid., p. 6. [90] Ibid.

Close also concluded that the hamstring muscles did not contribute substantially during normal walking.[91] Electrical activity in biceps femoris was slight in the normal subject during walking.[92]

A study of twenty patients with biceps transfers to the patella by Close showed that their characteristic swing phase pattern was retained. In two patients where swing phase activity persisted during walking, spontaneous stance phase activity developed when the subjects ascended stairs. Two patients with biceps transfer to the patella demonstrated complete conversion to the stance phase.[93]

Phasic activity was studied for many years by Scherb,[94] who used, at first, the method of manual palpation, with the subject walking on a treadmill. Averages from hundreds of patients were compiled. Scherb later checked the manual method with electromyography. He concluded that the gluteus medius, gluteus maximus, sartorius, biceps femoris, semitendinosus, and semimembranosus were active during walking.

Arenti used elaborate treadmill and myographic apparatus to study the muscles of the lower limb during walking. He found that the semitendinosus flexed the knee during the swinging of the limb. The semimembranosus acted mostly during the stance phase. The short head

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[91]Ibid., p. 51. [92]Ibid., p. 111. [93]Ibid., p. 98.

[94]R. Scherb, "Kinetisch-Diagnostiche Analyse von Fehstorgungen: Technick und Resultate der Myokinesigraphie," Zeitschribt der Orthopedie (supplementum), (Volume 82, 1952) (translation taken from Close, Motor Function in the Lower Extremity), p. 77.

of biceps femoris acted as a flexor during the swing phase and long head acted as a flexor during the stance phase.[95]

Hirschberg and Nathanson investigated the normal and abnormal gaits. They determined that six muscle groups, including the hip muscles, the quadriceps, and the hamstrings, showed electrical activity during the transition from swing to stance phase. The gluteus maximus continued to contract beyond the middle of the stance phase. At the transition from the stance to the swing, the adductors, and in some cases, the hamstrings contracted.[96]

Battye and Joseph[97] studied the action of some muscles in walking in both men and women. The muscles recorded were: tibialis anterior, soleus, quadriceps femoris, the hamstrings, flexors of the hip, gluteus medius, and gluteus maximus, and erector spinae. The tibialis anterior was found to have two phases of activity at the beginning and the end of the swing phase. The soleus contracted during the supporting phase. The quadriceps femoris showed two phases of activity--one towards the end of the swing phase and the other before the end of the stance phase. The hamstrings contracted during the second half of the swing phase and the early part of the stance phase

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[95]A. Arienti, "Analyse Oscillographique de la Marche de l'homme," Acta Physiotherapique-Rheumatique (Volume 3, 1948) (translation taken from Basmajian, Muscles Alive, p. 11.)

[96]G. Hirscberg and M. Nathanson, "Electromyographic Recording of Muscular Activity in Normal and Spastic Gaits," Archives of Physical Medecine (Volume 33, 1952), p. 217-228.

[97]C. K. Battye and J. Joseph, "An Investigation by Telemetering of the Activity of Some Muscles Used in Walking," Medical and Biological Engineering (Volume 4, 1965), p. 125-135.

and the latter part of the stance phase. The hip flexors contracted at the end of the swing phase and at the beginning of the stance phase. Gluteus medius was active during the first part of the stance phase, while the gluteus maximus was active at the end of the swing phase and the beginning of the stance phase. The erector spinae acted at the beginning and end of the stance phase. The investigators also concluded that the walking patterns of men and women were similar.

Electromyography with fine-wire electrodes and special equipment for synchronized motion pictures were used by Gray and Basmajian[98] to study six muscles of the leg and foot during walking in five different ways in ten "normal" and ten flatfooted subjects. Tibialis anterior had two peaks of activity at heel-stike and toe-off of the stance phase, but was active again at full-foot in flat-footed subjects. It was also more active in toe-out and toe-in walking. Tibialis posterior was inactive through the swing phase. In flatfooted subjects it became active at heel-strike and more active at full-foot during level walking. The toe-out walk reduced its activity. Flexor hallucis longus was most active in mid-stance. In toe-out walking, activity in this muscle increased in both phases, but it was more active in "normal" subjects. Peroneus longus was most active at mid-stance and heel-off and more active in flatfooted subjects. Abductor hallucis and flexor digitorum brevis were more active in flatfooted persons.

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[98]Edwin G. Gray and J. V. Basmajian, "Electromyography and Cinematography of Leg and Foot ("Normal" and Flat) during Walking," Anatomical Record, Volume 161 (Philadelphia: The Wistar Institute Press, 1968), pp. 1-15.

SUMMARY

Lateral asymmetry was a recognized postural deviation according to the works of the authorities researched. In the study by Klein and Buckley lateral asymmetry referred to an imbalance at the pelvic level. It was a rotation of the pelvis in the frontal plane about a sagittal-horizontal axis in such a manner that one iliac crest is lowered and the other is raised. Kelly considered lateral asymmetry to involve the whole body rather than the pelvic structure only. Lowman and Young recognized the existence of a sideward tilt of the pelvis. Cyriax, Clarke and Clarke, and Meuller and Christaldi also referred to lateral asymmetry of the pelvis. Clarke and Clarke maintained that curvatures of the spine did not necessarily accompany lateral asymmetry of the pelvis. All the authorities quoted agreed that lateral asymmetry was fairly common in the population. They also agreed that it was the more severe deviations which would affect the functions of the body in a detrimental fashion.

In their investigations, Davies, Heulster, Frost, Maple, and Spindler agreed that postural deviations, be they in the spine, legs, shoulders, or pelvis, if severe enough, will effect the normal, efficient functioning of the body. Davies, in her study of posture and motor ability, was unable, however, to find a significant relationship between postural deviations and the ability of the subjects to perform efficiently in motor ability tests. She stated specifically that postural divergencies had little relationship in gait divergencies. Heulster concluded that asymmetry was highest at the pelvic level during walking. Frost ascertained that there was some connection between anteroposterior curves and scoliosis. Maple demonstrated that certain age groups had different postural problems from other age groups, while Spindler connected anatomical deviations with physiological problems.

The following chart has been included to summarize what the authorities, quoted in the review of related literature, considered to be the muscles used during normal walking. The letter "p" will proceed the name of the muscle indicated a prime mover by the authorities.

AUTHOR	SWING PHASE	STANCE PHASE
J. R. Close	Beginning:	Beginning:
	biceps femoris (long head)	semimembranosus p
	Middle:	
	semimembranosus p semitendinosus p	
	End:	End:
	semimembranosus p semitendinosus p	biceps femoris (short head) p
J. V. Basmajian	semitendinosus p semimembranosus p	semimembranosus p biceps femoris (short head) p
K. Wells	Beginning:	Beginning:
	tensor fasciae latae p iliopsoas p sartorius p pectineus p rectus femoris biceps femoris (short head)	gluteus maximus p gluteus medius p gluteus minimus p quadriceps
	Middle:	
	biceps femoris p semitendinosus p semimembranosus p	

AUTHOR	SWING PHASE	STANCE PHASE
	End: biceps femoris (long head) adductor longus adductor magnus adductor brevis	End: adductor magnus adductor longus
Rasch and Burke	iliopsoas sartorius pectineus rectus femoris tensor fasciae latae biceps femoris semitendinosus semimembranosus	gluteus maximus
J. Joseph	tibialis anterior	calf muscles hamstrings gluteus maximus
Battye and Joseph	quadriceps femoris hamstrings gluteus maximus	quadriceps femoris hamstrings gluteus maximus gluteus minimus
MacConaill and Basmajian	semitendinosus biceps femoris (short head) hamstrings gluteus maximus	semimembranosus biceps femoris (long head) hamstrings gluteus maximus

In their investigation of muscles employed in walking, Saunders, et al., arrived at six determinants of gait. If more than one of these determinants was lost, effective compensation was impossible and the whole walking pattern was altered. Close determined through his investigations that a paralytic used his remaining musculature in a different fashion than a normal person. He concluded that the hamstrings were not active in walking and the biceps femoris only slightly active in the normal person. Scherb concluded that gluteus medius, gluteus maximus, sartorius, biceps femoris, semitendinosus, and semimembranosus were active during normal walking. Arienti determined that semitendinosus was active during the swing phase and that the short head of the biceps femoris was active during the swing phase, while semimembranosus was active during the stance phase and that the short head of the biceps femoris was active during the swing phase while the long head was active during the stance phase. Hirschberg and Nathanson determined that the hip muscles, the quadriceps, and the hamstrings were active during the transition from the swing phase to the stance phase. The gluteus maximus was active during the stance phase. There was no difference in the patterns of walking in men and women according to Battye and Joseph. They demonstrated that soleus acted in the stance phase, quadriceps in both phases, hamstrings in both phases, the hip flexors in the stance phase, gluteus medius in the stance phase, gluteus maximus in both phases, and the erector spinae acted during the stance phase. The investigation by Gray and Basmajian demonstrated that the postural fault of flatfoot affected the way the muscles were employed during walking.

On the whole, very little has been done to study the effects of lateral asymmetry on the muscles employed during walking.

Chapter 3

PROCEDURES OF THE STUDY

The present investigation entailed an electromyographical study of the effects of lateral asymmetry on selected muscles in the upper leg employed in walking on a treadmill. Ten female students enrolled at Eastern Illinois University in Charleston, Illinois, were divided into a test group, which demonstrated the condition defined as lateral asymmetry of the pelvis, and a reference group, which demonstrated symmetry of the pelvis.

In this chapter, selection of the subjects, instrumentation, pre-test preparation of the subjects, pre-test preparation of the electromyographic equipment, preparation of the subjects, and treatment of the data have been presented.

SELECTION OF THE SUBJECTS

Volunteer subjects were recruited from several physical education service classes and physical education professional classes at Eastern Illinois University. The purpose of the study and the requirements of the subjects were explained carefully. Twenty-five female college students volunteered to serve as subjects for the study. Some of the subjects were suspected of demonstrating lateral asymmetry. All twenty-five subjects were screened to determine if they were acceptable as test subjects, demonstrating one half inch deviation of the iliac crests of the pelvis, or reference subjects, demonstrating no deviation of the iliac crests of the pelvis.

The subject was asked to stand on a low stool placed in front of, and to the center of, a posture grid. The grid was constructed from a sign frame with a white sheet stretched tightly over it. Tape measures were fastened to the sides, top, and bottom of the grid. Dark cords were then nailed to the tape measures to divide the grid into square inches. The posture grid fitted into the doorway of the student lounge at McAfee Gymnasium, Eastern Illinois University.

Spotlights were located strategically behind the posture grid, inside the student lounge, and behind the camera to aid in the production of silhouettegraphs, which were taken to measure the deviation between the iliac crests. Silhouettegraphs are photographs which bring the background (the lines of the grid) into focus.

The iliac crests were palpated by the investigator and marked with thin strips of tape. The top of the strip of tape was placed flush with the top of the iliac crest. Dark tape was employed to contrast with the skin of the subjects.

The subject was asked to stand in the center of the stool, facing the grid. The feet were placed a comfortable distance apart, toes pointing straight forward. The head was held erect with the subject looking directly at the posture grid. The arms hung relaxed at the sides. The subject was asked to stand with her weight evenly distributed on both legs throughout the time she stood on the stool.

The location of the marked iliac crests was recorded by joining the lines of the grid on the silhouettegraphs and noting where the top of the tape was in relation to the lines. (Figure 6).

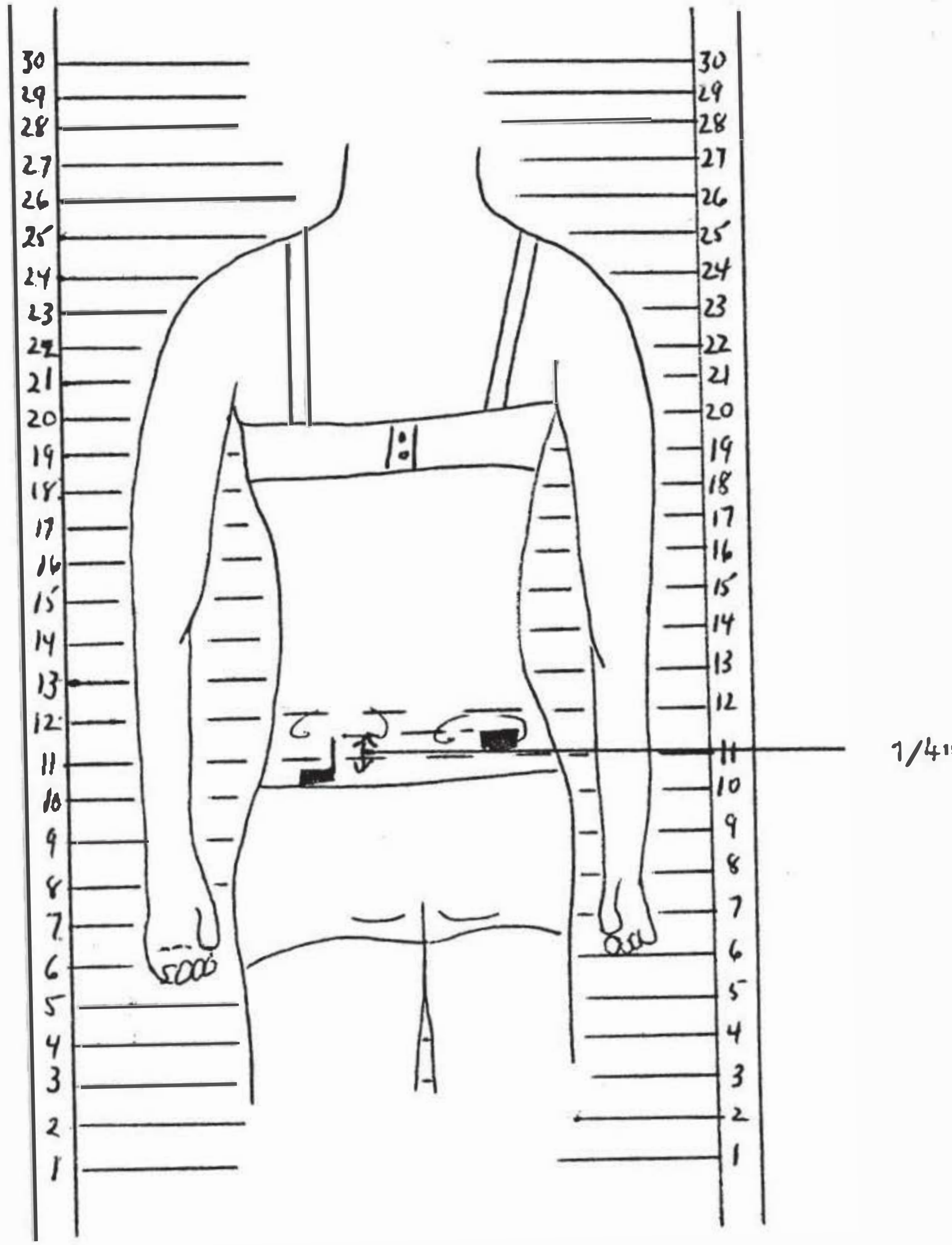

FIGURE 7

DIAGRAM REPRESENTING METHOD OF MEASURING ILIAC DEVIATION. THIS SUBJECT DEMONSTRATES A DEVIATION OF ONE QUARTER INCH BETWEEN THE TWO ILIAC CRESTS

The names of the subjects who met the qualifications of a test subject were placed on one list and the names of those who met the qualifications of a reference subject were placed on another list. Those subjects who demonstrated a deviation of less than half an inch were not considered as subjects for the study. The final test subjects were the first five on the list of subjects who qualified as test subjects and who demonstrated a willingness to proceed with the investigation. The five reference subjects were selected in the same manner. In this way randomization was insured since the investigator had no control over when the subjects could make themselves available for the screening session and, therefore, had no control over the order of possible test and reference subjects. The five test subjects were designated as Group A and the five reference subjects were designated as Group B.

INSTRUMENTATION

Introduction

Electromyography is the recording and the study of muscle action potentials.[99] Muscle action potentials are the electrical changes that occur in a contracting muscle.[100] These changes can be detected by sensitive electrical equipment and recorded on various instruments as a distinctive pattern of action potentials (lines with varying spike formations). The equipment needed for electromyography

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[99] Herbert deVries, Physiology of Exercise for Physical Education and Athletics (Dubuque, Iowa: William C. Brown Co., 1963), p. 191.

[100] Ibid., p. 22.

can range from a simple four-channel physiograph adapted for electromyograms through the use of proper preamplifiers to the sophisticated all-inclusive console units with up to thirty-two channels and attachments to such recording devices as an oscilloscope, pen recorder, tape recorder, loud speaker, and a device for taking instantaneous photographs of the electromyograms at any given moment. Several separate components comprised the electromyographic equipment utilized in the study.

The Physiograph

The physiograph was the monitor[101] which received the action potentials detected by the electrodes. The electrical impulses are amplified by the monitor and then applied to one or more appropriate display mediums.[102] Considerable amplification was required for recording electromyograms, since the voltage created by the electrical change in the acting muscle and detected by the electrodes are minute (in the order of tens or hundreds of microvolts).[103] These minute voltages must be greatly amplified before they are of a sufficient level to appear on the display medium.

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[101]This term was used by Charlotte Scott in her Doctoral Dissertation, "A Quantitative Electromyographic Study of the Trapezius During Selected Exercises Designated as Round Shoulders" (Denton, Texas: Texas Woman's University, 1969), p. 50.

[102]Sidney Licht (ed.), Electrodiagnosis and Electromyography (New Haven, Connecticut: Elizabeth Licht Pub., 1961), p. 45.

[103]Ibid.

The monitor utilized for the study was a Narco Bio-Systems Physiograph, model Four[104] with a display medium consisting of a pen recorder.

The muscle action potentials were displayed by the pen recorder on recording paper divided into sections of five millimeters square. The paper speed control was set on five cetimeters per second.

Recording Apparatus

The physiograph had a built-in recorder in the form of recording channels. Each recording channel includes a channel amplifier, a pen motor and inking assembly. The amplitude control determines the sensitivity of the recording channel when the input device does not have an amplitude control. The position control placed the channel pen on the recording paper.[105] For the purposes of the study the recording apparatus was referred to as a pen recorder.

Hi-Gain Preamplifiers

The muscle action potentials were amplified for the production of electromyograms by two Hi-Gain preamplifiers, products of Narco Bio-Systems.[106] The preamplifiers were on loan from the Psychology Laboratory and the Zoology Department of Eastern Illinois University. The high gain preamplifier

> . . . is a differential capacitor coupled preamplifier with sufficient voltage gain and frequency selectivity to record

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[104]Narco Bio-Systems Inc., 7651 Airport Blvd., Box 12511, Houston, Texas 77017.

[105]Narco Bio-Systems, E & M Physiograph Instruction Manual (Houston), pp. 2-5.

[106]Narco Bio-Systems, op. cit.

> all ranges of bioelectric potentials. Maximum sensitivity exceeds thirty microvolts/centimeters of physigraph pen deflection.[107]

The time constant switch was set on three thousandths of a second (0.03) which allowed the preamplifiers to keep transients and artifacts to a minimum. The three thousandths of a second position on the selector switch was the desired setting for electromyograms as designated by the letters, "E.M.G.," on the switch."[108]

Electrodes

A satisfactory recording of muscle action potentials depends on the selection of electrode placement, proper attachment to the skin, and proper preparation of the skin of the subjects. It was generally considered that the best location for electrode placement was over the belly of the muscle near the motor points. The electrodes were placed on either side of the motor points and not more than one inch apart. The motor points were located through the use of the diagrams found in The Extremities[109] by Quiring and Warfel.

The electrodes were purchased from Narco Bio-Systems. The silver-disc electrodes were housed in plastic coverings which could be attached to the surface of the skin via double adhesive washers. This was reinforced by taping the electrodes to the surface of the skin by adhesive bandages and wrapping the leg with elastic (tensor) bandages where possible. This method of ensuring electrode adhesiveness

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[107]Narco Bio-Systems, Manual, op. cit., pp. 35-60.

[108]Ibid., pp. 35-61.

[109]Daniel P. Quiring and John H. Warfel, The Extremities (Philadelphia: Lea and Febiger, 1960).

was suggested by the athletic trainer for Eastern Illinois University, Mr. Dennis Aten.

The actual method of preparing the subject will be discussed later in the chapter.

PRE-TEST PREPARATION OF THE SUBJECT

Prior to any electromyographic work, the subject was asked to report to the Human Performance Laboratory in Lantz Gymnasium, Eastern Illinois University for a short session on two separate days to orient the subject to the laboratory and the treadmill. The operation of the treadmill and the reason for its use in the study was explained to the subject. The subject was then asked to step onto the treadmill. She was instructed to hold onto the support bar while the treadmill was started. The treadmill was stopped and started a number of times to accustom the subject to the slight jerks which accompanied these maneuvres. When the subject had walked for five minutes on the treadmill, she was encouraged to remove one hand from the support bar and then the other until she was walking relaxed and unencumbered.

PRE-TEST PREPARATION OF ELECTROMYOGRAPHIC EQUIPMENT

The following procedures were carried out before any of the subjects reported to the Human Performance Laboratory. The physiograph main switch and the channel switches were turned on at least one half hour before the subject arrived for testing in order to allow the monitor sufficient time to warm up. The recording apparatus was checked to ascertain that the ink was flowing smoothly. The channels were calibrated to correct for drift and for synchronization. The monitor was calibrated by tapping the biceps femoris of the subject before the final electromyograms were taken. The equipment was also checked at this point for artifact.

The investigator checked the paper supply and the supply of the electrode paste. The electrodes were cleaned and prepared for the subject.

PREPARATION OF THE SUBJECT

The subject was asked to report to the session wearing a loose pair of shorts or a two-piece bathing suit. Tightly fitting clothing would rub against the electrode and provide artifact in recording. The subject was also asked to shave her legs on the day of her laboratory session. This would make the removal of any tape less painful for the subject.

A girth measurement was taken for each leg. A tiny pencil mark was made on the skin of the subject seven inches above the patella to ensure consistancy in measurement. Three measurements of each leg were taken with an anthropometric tape measure at the marked point on the skin. The average measurement was computated for each leg.

The subject was then prepared for the electromyograms. The motor points were located and marked with a grease pencil. In order to locate the desired motor points the diagrams of Quiring and Warfel[110] and muscle palpation were used.

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[110]Quiring and Warfel, op. cit.

Redux Creme,[111] a formula electrolyte that emulsifies skin oils and provides a conductive medium between skin and electrode, was placed on a stiff toothbrush. The areas of electrode application for the first set of muscles to be recorded and the inside of both wrists were vigorously rubbed with the toothbrush. The wrists were used as the ground. A double adhesive washer was placed on the electrode and Redux Creme was placed on the concave portion of the electrode. The electrode was then attached to the surface of the prepared skin. Any excess electrode paste was wiped off with a tissue. The electrode was then taped to the surface of the skin with adhesive bandages, and in the case of biceps femoris, semitendinosus, and sartorius, the area around the electrode was wrapped with an elastic bandage.

After the first set of muscles, the biceps femoris of the right leg and the left leg, was recorded, the dominant leg of the subject was noted. The dominant leg, defined for the specific activity of walking, was considered to be the first leg the subject stepped on when initiating a walk from a relaxed stand. The treadmill was stopped and started three times and each time the leg on which the subject first stepped was noted. The leg initiating the walk most often was considered to be the dominant leg. The subject was not informed of the purpose of the stopping and starting of the treadmill in order to ensure that the initiating of the walk was a natural, and unanticipated act.

After each set of muscles was studied the subject stepped down from the treadmill and the electrodes were removed, cleaned, and moved

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[111] Hewlett Packard, Medical Electronics Division, 175 Wyman Street, Waltham, Mass.

to the motor points of the next set of muscles. The muscles were studied in sets of two--the same muscle on each of the two legs at one time. The muscles were recorded in the following order: biceps femoris, semitendinosus, sartorius, gluteus maximus, and gluteus medius.

The subject was instructed to walk normally on the treadmill. The speed of the walk was regulated by setting the speed of the treadmill at three miles per hour. The walk was a heel-toe action walk. The subject was encouraged to relax as much as possible. To aid this the investigator maintained a friendly atmosphere and made the subject her first consideration during the laboratory session.

The subject was asked to hold the lead wires connecting the electrodes to the physiograph. This prevented the metal portions of the leads from hitting against each other or the support bar of the treadmill and possibly creating artifact in the electromyograms.

The stance and the swing phase was recorded by marking the action potential spike on the electromyogram whenever the right heel of the subject contacted the treadmill. The procedure was repeated for the left leg. The name of the subject and the muscle studied was also recorded on the electromyogram.

A strength measurement for each leg was taken after the recording of the electromyograms was completed. The subject was taken into the Fitness Room, adjoining the laboratory, and asked to complete a maximum leg press with each leg. The subject lay on her back under the leg press bar. She then stretched each leg up to the straight leg position pushing the weight up on the sliding bar. Weights were added to the leg press until the subject could no longer lift the weights with either of her legs. The subject was allowed to rest between leg lifts in order to partially alleviate the fatigue factor. The maximum weight the subject could lift with each leg was recorded.

The girth measurements and strength measurements were taken to augment the information gleaned from the electromyograms. It was believed by the investigator that the subjects with lateral asymmetry would have one leg that was stronger than the other while the subjects with symmetry of the pelvis would not have an appreciable difference in the strengths of the two legs. Similarly it was believed by the investigator that the test subjects would have one leg that measured more in girth than the other, while there would be no appreciable difference in the girth measurements of the legs of the reference group.

After the testing session was completed the equipment was cleaned and prepared for the next subject.

TREATMENT OF THE DATA

There are a number of ways electromyographical data may be treated. Some problems of dealing with electromyographical data, some possible methods of treating the data, and the method chosen for the study are presented in the following paragraphs. Basmajian stated that

> evaluation of the recordings, whatever their type, is the most abused part of electromyography. Part of the difficulty stems from the use of poor records and part from inexperience. . . .
>
> Evaluation of any record is, of necessity, of two types--quantitative and qualitative. Many investigators have confused these two classes while others have assumed that any but quantitative results are not reliable. Most electromyographic records must be considered by both criteria and, although this approach imposes a discipline that quantitative results alone appear not to demand, it is more reliable.
>
> Many attempts have been made to make electromyography purely quantitative. For example, integration of the electrical potentials mechanically or electronically has been used.

> Bergstrom recently (1959) has claimed the simple counting of spikes is a quantitative reflection of the amount of muscular activity, and we are presently trying to confirm his claim which appears to be true within narrow limits.
>
> Experience has shown that the easiest and, in most cases, most reliable evaluation is by the trained observer's visual evaluation of results coloured by his knowledge of the technique involved. Indeed, not only are the number of spikes a factor but the amount of superimposition (summation) of spikes, and their height and type, are important too.[112]

The results of an electromyogram can be classified on a scale from zero to three where zero equals no activity, one equals slight activity (single action potentials can be distinguished--the base line is not covered with action potentials), two equals moderate activity (separate action potentials can be distinguished--the base line is covered with action potentials), and three equals marked activity (separate action potentials can no longer be distinguished).[113]

The amplitude of the spikes was measured in centimeters at three different places on the recordings. A mean from the three amplitude measurements was computated and recorded.

The two-way analysis of variance design was employed to determine whether or not the difference found between the spike amplitude of the muscles studied electromyographically on the subjects with lateral asymmetry (Group A) was significantly different from the spike amplitude for the subjects with no lateral asymmetry of the pelvis (Group B). The level of confidence was set at five percent. The information was then computed by the computer in the Eastern Illinois Data Processing Room.

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[112]J. V. Basmajian, Muscles Alive, Their Functions Revealed by Electromyography (Baltimore: The Williams and Wilkins Co., 1967), p. 46.

[113]Ibid., p. 47.

The information concerning the girth and strength measurements was treated objectively rather than statistically by comparing the overall results from both groups.

Chapter 4

PRESENTATION OF THE FINDINGS AND INTERPRETATION OF THE DATA

The study was an electromyographical investigation to determine the effects of lateral asymmetry on selected muscles of the upper leg during the action of normal walking on a treadmill. The electromyograms of five muscles (biceps femoris, semitendinosus, sartorius, gluteus maximus, and gluteus medius) of five subjects demonstrating the condition of lateral asymmetry were compared with the electromyograms of five reference subjects demonstrating symmetry of the pelvis.

Girth and strength measurements of each leg of the five test subjects and five reference subjects were taken to augment the findings of the electromyograms. It was believed that the reference group would show no appreciable difference in girth and strength measurements when compared with each subject in the test group, whereas the test subjects would.

Spike amplitudes for the stance phase and the swing phase of the right leg and then the left leg for each of the five muscles of the five subjects in the test group and of the five subjects in the reference group were calculated. These amplitudes were compared by means of two-way analysis of variance designs in order to determine if there was a significant difference between the spike amplitudes of the test group and of the reference group. Specifically, the difference between the spike amplitudes of the biceps femoris, semitendinosus, sartorius, gluteus maximus, and gluteus medius, stance phase and swing phase for each, of the test group and reference group was calculated. The actual computations were analyzed by the computer in the Data Processing Room at Eastern Illinois University.

In the following chapter, an analysis of the data will be presented and interpreted.

ANALYSIS OF GIRTH AND STRENGTH MEASUREMENTS

Test subject A_1 had a girth measurement of 47.0 centimeters for the right leg and 47.9 centimeters for the left leg. The dominant leg was the right leg and it was 0.9 centimeters slimmer than the other leg. This subject had a lateral asymmetry deviation of the pelvis to the left. This meant that the right leg was the longer. With the right leg the subject pressed 65 pounds and with the left 95 pounds.

Subject A_2 measured 45.0 centimeters around the right leg and 43.7 centimeters around the left. The left leg, the dominant leg, was 1.3 centimeters slimmer than the other leg. However, the dominant leg, and incidentally the longer leg, was the slimmer. Subject A_2 pressed 105 pounds with the right leg and 115 pounds with the left leg.

The girth measurements of the right and left leg of Subject A_3 were 48.06 centimeters and 47.16 centimeters respectively. The left leg was the dominant leg, and as suspected, it was the slimmer leg by 0.8 centimeters. However, the deviation was to the left, leaving the right leg, the non-dominant leg, as the longer leg. Subject A3 pressed 70 pounds with the right leg and 85 pounds with the left leg.

The right leg of Subject A_4 measured 51.96 centimeters in girth while the left leg measured 49.9 centimeters, leaving a difference of 2.06 centimeters. In this case the dominant leg (the right leg) was not the slimmer one. Furthermore, the deviation occurred to the right, which meant that the left leg was the longer one. With the dominant leg the subject pressed 190 pounds and with the left leg, 175 pounds, a difference of 25 pounds in favor of the dominant leg.

Like Subject A_4, Subject A_5 had a deviation to the right, meaning that the left leg was the longer one, but the right leg was the dominant leg. The left leg was the slimmer by 0.2 centimeters. The right leg measured 50.05 centimeters and the left, 50.03. The subject pressed 135 pounds with each leg.

From the test subjects alone, it appeared that the dominant leg might be the stronger, but the evidence is not conclusive. In three of the five subjects the dominant leg was the stronger (by 10, 15, and 15 pounds respectively). In one case the subject had equal strength in both legs and in the case of Subject A_5 the dominant leg was the weaker by 30 pounds. Whether the deviation was to the right or left did not appear to make any difference as to which leg was the dominant, the stronger, or the smaller in girth measurement.

In three of the test subjects the dominant leg was the slimmer seemingly because it was used more and would, therefore, be more muscular and have less fatty tissue on it.

Subject B_1, the first of the reference subjects, demonstrated a girth measurement of 52.17 centimeters for the right leg and 52.60 centimeters for the left leg. The dominant leg was the right leg.

There was no difference in the weight pressed by either of the legs. The weight pressed was 170 pounds.

The dominant, right, leg of Subject B_2 measured 52.13 centimeters, 0.17 centimeters slimmer than the left leg. This subject also showed no difference in leg strength, pressing 145 pounds with both legs.

The results from Subject B_3 did not hold true to the belief that the dominant leg would be the slimmer one. The left leg (the non-dominant leg) was the slimmer by 0.71 centimeters. The left leg measured 48.19 centimeters and the right leg measured 48.90 centimeters. However, she demonstrated a stronger dominant leg, pressing 145 pounds with the right leg and only 135 pounds with the left leg.

Like Subject B_3, Subject B_4 demonstrated that the dominant leg was not always the slimmer one. The right leg was slimmer than the left by 0.83 centimeters. The right leg had a girth measurement of 48.03 centimeters and the dominant leg one of 48.86 centimeters. There was no difference in the weight pressed--105 pounds by both legs.

The dominant leg (the right leg) of Subject B_5 measured 52.10 centimeters while the left leg measured 51.26 centimeters. However, this subject pressed only 90 pounds with her dominant leg and 140 pounds with her left leg. She later stated that the marked difference might be due to a bone disease which limited her performance whenever pain set in as it did during the leg press. Pain was no problem to her in the simple action of walking.

Like Group A, Group B demonstrated that the dominant leg was not always the stronger leg or the slimmer leg in girth. However, Group A demonstrated a greater difference in the weight pressed by both legs than did Group B. This, however, did not appear to be linked to the occurance of lateral deviation.

Thus, no conclusive evidence was found showing that the subjects demonstrating the condition defined as lateral asymmetry had an appreciable difference in the strength of the two legs and in girth measurements of the two legs when compared with the subjects demonstrating symmetry of the pelvis.

Table 1 gives a summary of the information described in the preceding paragraphs.

ANALYSIS OF THE DIFFERENCE OF MUSCLE SPIKE AMPLITUDES OF THE FIVE SELECTED MUSCLES DURING THE TWO PHASES OF WALKING OF THE TWO GROUPS

A two-way analysis of variance for equal groups was used to compare the muscle spike amplitudes obtained from the electromyograms of the five selected muscles (biceps femoris, semitendinosus, sartorius, gluteus maximus, and gluteus medius) of the test group (Group A) and those of the reference group (Group B) for the purposes of determining statistical differences.

Biceps Femoris

Stance phase. No significant difference existed between the subjects in the test group and the subjects in the reference group for the biceps femoris, stance phase, as evidenced by an F ratio of 0.054. There was no significant difference between the right and left legs of the two groups compared within the group nor between the two legs

Table 1

Data Chart for Group A (Test Group) and B (Reference Group) Presenting Pertinent Information on Girth Measurements, Strength Measurements, Dominant Leg, and Pelvic Tilt

Group	Subject	Dom. Leg	Dev.	Girth Rt.	Girth Lt.	Strength Rt.	Strength Lt.
	1	right	left	47.00 cm.	47.90 cm.	65 lb.	95 lb.
	2	left	right	45.00 cm.	43.70 cm.	105 lb.	115 lb.
A	3	left	left	48.06 cm.	47.16 cm.	70 lb.	85 lb.
	4	right	right	51.96 cm.	49.90 cm.	190 lb.	175 lb.
	5	right	right	50.50 cm.	50.03 cm.	135 lb.	135 lb.
	1	right		52.17 cm.	52.60 cm.	170 lb.	170 lb.
	2	right		52.13 cm.	52.30 cm.	145 lb.	145 lb.
B	3	right		48.90 cm.	48.19 cm.	145 lb.	135 lb.
	4	left		48.03 cm.	48.86 cm.	105 lb.	105 lb.
	5	right		52.10 cm.	51.26 cm.	90 lb.	140 lb.

of one group compared with the two legs of the other group as evidenced by the F ratios of 0.616 and 1.233, respectively. Table 2 presents a summary of the two-way analysis of variance for the biceps femoris, stance phase, left and right leg, for the test group and the reference group.

Table 2

Analysis of Variance Summary Table for the Biceps Femoris Stance Phase Right and Left Leg of the Test Group and Reference Group

Source	SS	df	ms	F
Between Subjects	2.868	9		
Between Groups	0.019	1	0.019	0.054
$Error_b$	2.849	8	0.356	
Within Subjects	1.683	10		
Between Legs	0.105	1	0.105	0.616
Legs X Groups	0.211	1	0.211	1.233
$Error_w$	1.367	8	0.171	
Total	4.551	19		

F (1.8) (.05) = 5.32

Swing phase. There was no significant difference between the test group and the reference group in the spike amplitudes for the biceps femoris, swing phase, of the two groups. The F ratio between groups was 0.656, between the legs it was 0.373, and between the interaction term it was 0.578. Table 3 presents a summary of the two-way analysis of variance for the biceps femoris, swing phase, for the test group and the reference group.

Table 3

Analysis of Variance Summary Table for the Biceps Femoris Swing Phase Right and Left Leg of the Test Group and Reference Group

Source	SS	df	ms	F
Between Subjects	2.653	9		
Between Groups	0.201	1	0.201	0.656
$Error_b$	2.452	8	0.306	
Within Subjects	1.791	10		
Between Legs	0.075	1	0.075	0.373
Legs X Groups	0.116	1	0.200	0.578
$Error_w$	1.601	8	0.200	
Total	4.444	19		

F (1.8) (.05) = 5.32

Semitendinosus

Like the biceps femoris, no significant difference between the spike amplitudes of the semitendinosus for the stance phase or the swing phase between Group A and Group B was found. However, there was more of a difference in this muscle than in the biceps femoris.

Stance phase. The F ratio between groups A and B for the stance phase of the semitendinosus muscle was 2.452. The F ratio between the legs was 2.073, and between the interaction term it was 0.020. The analysis showed that there was less of a difference in the interaction term than between the groups or the legs.

Swing phase. The swing phase of the semitendinosus muscle demonstrated an F ratio of 0.056 between the two groups, an F ratio of

0.038 between the legs, and an F ratio of 0.270 for the interaction term.

Tables 4 and 5 present a summary of the two-way analysis of variance for the semitendinosus, stance phase and swing phase, respectively.

Table 4

Analysis of Variance Summary Table for the Semitendinosus Stance Phase Right and Left Leg of the Test Group and Reference Group

Source	SS	df	ms	F
Between Subjects	7.317	9		
Between Groups	1.717	1	1.717	2.452
$Error_b$	5.602	8	0.700	
Within Subjects	2.732	10		
Between Legs	0.561	1	0.561	2.073
Legs X Groups	0.005	1	0.005	0.020
$Error_w$	2.165	8	0.271	
Total	10.050	19		

F (1.8) (.05) = 5.32

Sartorius

There was no significant difference in the spike amplitudes in the sartorius, both phases.

Stance phase. The F ratio between the groups for the stance phase was 0.075. There was more of a difference, however, between the legs as evidenced by the F ratio of 3.449. The interaction term had an F ratio 1.139. Table 6 presents a summary of the two-way analysis of variance for the sartorius, stance phase.

Table 5

Analysis of Variance Summary Table for the Semitendinosus Swing Phase Right and Left Leg of the Test Group and Reference Group

Source	SS	df	ms	F
Between Subjects	3.879	9		
Between Groups	0.027	1	0.027	0.056
$Error_b$	3.852	8	0.481	
Within Subjects	2.534	10		
Between Legs	0.012	1	0.012	0.038
Legs X Groups	0.082	1	0.082	0.270
$Error_w$	2.440	8	0.305	
Total	6.413	19		

F (1.8) (.05) = 5.32

Table 6

Analysis of Variance Summary Table for the Sartorius Stance Phase Right and Left Leg of the Test Group and Reference Group

Source	SS	df	ms	F
Between Subjects	2.407	9		
Between Groups	0.022	1	0.022	0.075
$Error_b$	2.385	8	0.298	
Within Subjects	0.828	10		
Between Legs	0.227	1	0.227	3.449
Legs X Groups	0.075	1	0.075	1.139
$Error_w$	0.526	8	0.066	
Total	3.235	19		

F (1.8) (.05) = 5.32

Swing phase. The F ratio between groups for the swing phase of the sartorius was 0.549, between the legs it was 0.892, and between the interaction term it was 1.612. The summary for the two-way analysis of variance for the swing phase of the sartorius is presented in Table 7.

Table 7

Analysis of Variance Summary Table for the Sartorius Swing Phase Right and Left Leg of the Test Group and Reference Group

Source	SS	df	ms	F
Between Subjects	7.446	9		
Between Groups	0.478	1	0.478	0.549
$Error_b$	6.968	8	0.871	
Within Subjects	1.007	10		
Between Legs	0.086	1	0.086	0.892
Legs X Groups	0.155	1	0.155	1.612
$Error_w$	0.767	8	0.096	
Total	8.453	19		

$F\ (1.8)\ (.05) = 5.32$

Gluteus Maximus

Stance phase. The F ratio between groups for the stance phase of the gluteus maximus 0.101, for the legs it was 0.470, and for the interaction term it was 0.122. This demonstrated that there was no significant difference between the spike amplitudes of the gluteus maximus, stance phase, between the test group and the reference group. Table 8 presents the summary of the two-way analysis of variance for the gluteus maximus, stance phase.

Table 8

Analysis of Variance Summary Table for the Gluteus Maximus Stance Phase Right and Left Leg of the Test Group and Reference Group

Source	SS	df	ms	F
Between Subjects	1.742	9		
Between Groups	0.022	1	0.022	0.101
$Error_b$	1.721	8	0.215	
Within Subjects	1.160	10		
Between Legs	0.063	1	0.063	0.470
Legs X Groups	0.016	1	0.016	0.122
$Error_w$	1.080	8	0.135	
Total	2.902	19		

F (1.8) (.05) = 5.32

Swing phase. The spike amplitude of the gluteus maximus, swing phase, demonstrated a slightly greater difference between the test and reference groups than did the gluteus maximus, stance phase. Still the difference was not significant as evidence by the F ratio between groups of 0.301, by the F ratio between legs of 0.005 and by the F ratio of the interaction term of 0.282. The summary of the two-way analysis of variance for the gluteus maximus, swing phase, has been placed in Table 9.

Gluteus Medius

Stance phase. One muscle demonstrated a significant difference between spike amplitudes between the two groups. In order to be significantly different the F ratio would have to be 5.320 or greater at the five percent level of confidence. Since the F ratio for the

Table 9

Analysis of Variance Summary Table for the Gluteus Maximus Swing Phase Right and Left Leg of the Test Group and Reference Group

Source	SS	df	ms	F
Between Subjects	2.276	9		
Between Groups	0.083	1	0.083	0.301
$Error_b$	2.193	8	0.274	
Within Subjects	0.623	10		
Between Legs	0.000	1	0.000	0.005
Legs X Groups	0.021	1	0.021	0.282
$Error_w$	0.601	8	0.075	
Total	2.898	19		

$F\ (1.8)\ (.05) = 5.32$

gluteus medius, stance phase, was 6.657, it easily demonstrated a significant difference. However, there was no significant difference between legs as evidenced by the *F* ratio between legs of 1.112 nor between the interaction term as evidenced by the *F* ratio of 0.315. Table 10 presents the summary of the two-way analysis of variance for the gluteus medius, stance phase.

Swing phase. No significant difference in the spike amplitudes of the gluteus medius, swing phase, between the test group and the reference group was determined. This is evidenced by the *F* ratio between groups of 0.316, between legs of 1.068, and between the interaction term of 0.161. Table 11 presents the summary of the two-way analysis of variance for the gluteus medius, swing phase.

Table 10

Analysis of Variance Summary Table for the Gluteus Medius Stance Phase Right and Left Leg of the Test Group and Reference Group

Source	SS	df	ms	F
Between Subjects	6.710	9		
Between Groups	3.047	1	3.047	6.657
$Error_b$	3.662	8	0.458	
Within Subjects	3.123	10		
Between Legs	0.376	1	0.376	1.112
Legs X Groups	0.046	1	0.046	0.135
$Error_w$	2.702	8	0.338	
Total	9.833	19		

F (1.8) (.05) = 5.32

Table 11

Analysis of Variance Summary Table for the Gluteus Medius Swing Phase Right and Left Leg of the Test Group and Reference Group

Source	SS	df	ms	F
Between Subjects	5.363	9		
Between Groups	0.204	1	0.204	0.316
$Error_b$	5.519	8	0.645	
Within Subjects	2.248	10		
Between Legs	0.260	1	0.260	1.068
Legs X Groups	0.039	1	0.039	0.161
$Error_w$	1.949	8	0.244	
Total	7.611	19		

F (1.8) (.05) = 5.32

Chapter 5

SUMMARY, CONCLUSIONS, DISCUSSION OF THE FINDINGS, AND RECOMMENDATIONS FOR FURTHER STUDIES

SUMMARY OF THE INVESTIGATION

It has long been acknowledged that pathological postural faults affect the efficient functioning of the human body in motion. The question is whether a non-pathological fault, such as lateral asymmetry at the pelvic level, would hinder, in significant manner, efficient functioning of the body.

The purpose of the study was to determine through electromyography the effects of lateral asymmetry at the pelvic level on the action of normal walking on a treadmill. The action potentials of the biceps femoris, semitendinosus, sartorius, gluteus maximus, and gluteus medius of subjects with lateral asymmetry were recorded electromyographically while the subject walked on a treadmill. These were compared with similar recordings of the muscle action potentials of subjects with no lateral asymmetry of the pelvis. It was hypothesized that there would be no significant difference in the action potentials between the two groups.

Twenty-five female students from Eastern Illinois University, Charleston, Illinois, were screened to determine whether or not they demonstrated one half inch lateral deviation at the pelvic level. On the basis of the results of the screening session five test subjects demonstrating one half inch lateral deviation of the pelvis and five reference subjects demonstrating no lateral deviation of the pelvis were selected. Electromyograms for each of these subjects were taken while they walked on a treadmill set at three miles per hour and zero percent grade. Amplitudes for the action potentials of each of the five muscles, stance phase and swing phase, of the five test subjects and five reference subjects were computed. The results from the test subjects were compared with those of the reference subjects by the two-way analysis of variance statistical method. The actual computations were completed by the computer in the Data Processing Room, Eastern Illinois University. Girth measurements and strength measurements for the right and left leg of each subject were taken and then the results of the test group were compared with those of the reference group.

CONCLUSIONS

The study revealed the following conclusions:

1. Lateral asymmetry has no effect on the difference of strength measurements and girth measurements between the right and left leg.

2. There is no difference in the spike amplitudes of the biceps femoris, stance phase, between people with lateral asymmetry and people without this postural deviation.

3. There is no difference in the spike amplitudes of the biceps femoris, swing phase, in people with lateral asymmetry and people without it.

4. There is no difference in the spike amplitudes of stance phase of the semitendinosus between the two categories of people.

5. There is no difference in the spike amplitudes of the stance phase of the semitendinosus.

6. There is no difference in the spike amplitudes of the sartorius, stance phase.

7. There is no difference in the spike amplitudes of the gluteus maximus, stance phase.

8. There is no significant difference in the spike amplitudes of the gluteus maximus, stance phase.

9. There is no difference in the spike amplitudes of the gluteus maximus, swing phase.

10. However, there is a significant difference between the spike amplitudes of the gluteus medius, stance phase, of people with lateral asymmetry and people without lateral asymmetry.

11. There is no significant difference in the spike amplitudes of the swing phase of the gluteus medius.

12. The data collected for the study failed to provide enough difference (since only one phase of one muscle demonstrates an important amount of difference between people with lateral asymmetry and people without this condition) to warrant rejection of the null hypothesis. Therefore, the statement that there would be no difference in the action potentials of certain muscles in the upper leg of subjects with lateral asymmetry recorded electromyographically while the subject walked on a treadmill when compared with similar recordings of the muscle action potentials of subjects with no lateral asymmetry of the pelvis must stand.

DISCUSSION OF THE FINDINGS

The electromyograms taken for the two groups demonstrate that each subject in both groups has her own individual walking pattern. Some use their muscles more forcefully than the others and it makes no difference to which group they belong. However, they all employ the same muscles during the stance phase of walking and during the swing phase of walking.

Although the test group employs the same muscles in the stance phase of walking and in the swing phase as does the reference group, there is a slight difference. This slight difference demonstrates that the test group compensates somewhat for the lateral tilt in the pelvis. The evidence, however, is not great enough to demonstrate a significant difference in the way the test group employed the five muscles studied in the action of walking as compared with the reference group.

The $\underline{F}$ ratio (6.657) for the gluteus medius between groups for the stance phase was the only one that demonstrates a significant difference. This substantiates the belief that the test group might be compensating for the lateral deviation at the pelvic level. However, the lateral deviation does not greatly affect the efficiency of the walking movement of the test group.

The reason for the significant difference in the gluteus medius stance phase may be explained by the anatomical location of this muscle. The gluteus medius lies over the area where a lateral tilt in the pelvis would occur; therefore, it would be shortened on one side and lengthened on the other. The related literature stated that the gluteus medius was employed during the stance phase but not during the swing phase which may serve to explain the lack of a significant difference between the two groups in the swing phase of the gluteus medius.

The difference between the girth and strength measurements between the legs of one group compared with the girth and strength measurements of the other group fails to demonstrate that lateral asymmetry has an effect on this area of the study. This helps to substantiate the findings from the electromyograms that the postural fault of lateral asymmetry at the pelvic level does not greatly affect the efficient functioning of the body. However, the test group shows a greater difference in strength measurements between the two legs than does the reference group. In spite of the fact that it is not directly related to the side on which the lateral deviation occurred, the postural fault might have a slight effect on the strength of the two legs in the test subjects.

RECOMMENDATIONS FOR FURTHER STUDIES

The following suggestions are recommended for further investigation:

1. A repetition of the study using more subjects and needle electrodes.

2. A repetition of the study using subjects with a lateral deviation to the right only or to the left only, not a mixed group.

3. A more detailed study of the differences between the girth and strength measurements between the test group and reference group using more subjects and using a test group with a deviation to either the right side or the left side, but not a mixed group.

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APPENDIXES

APPENDIX A

CHART REPRESENTING THE RESULTS OF THE MEASUREMENTS OF THE AMPLITUDES OF THE BICEPS FEMORIS, STANCE PHASE FOR GROUP A AND GROUP B

Group	Subject	Right Leg	Left Leg
A	1	1.133 cm.	0.917 cm.
	2	1.333 cm.	0.667 cm.
	3	0.542 cm.	0.442 cm.
	4	1.450 cm.	1.708 cm.
	5	0.433 cm.	1.458 cm.
B	1	1.000 cm.	0.916 cm.
	2	1.917 cm.	1.083 cm.
	3	0.125 cm.	0.525 cm.
	4	1.667 cm.	0.800 cm.
	5	0.900 cm.	0.533 cm.

APPENDIX B

CHART REPRESENTING THE RESULTS OF THE MEASUREMENTS OF THE AMPLITUDES OF THE BICEPS FEMORIS, SWING PHASE FOR GROUP A AND GROUP B

Group and Subject		Right Leg	Left Leg
	1	1.442 cm.	1.308 cm.
	2	2.333 cm.	0.925 cm.
A	3	1.287 cm.	0.825 cm.
	4	0.950 cm.	1.517 cm.
	5	0.767 cm.	0.833 cm.
	1	0.583 cm.	0.500 cm.
	2	1.967 cm.	1.250 cm.
B	3	0.583 cm.	1.100 cm.
	4	1.133 cm.	1.633 cm.
	5	1.750 cm.	0.683 cm.

APPENDIX C

CHART REPRESENTING THE RESULTS OF THE MEASUREMENTS OF THE AMPLITUDES OF THE SEMITENDINOSUS, STANCE PHASE FOR GROUP A AND GROUP B

Group	and Subject	Right Leg	Left Leg
	1	1.083 cm.	0.583 cm.
	2	0.400 cm.	0.417 cm.
A	3	0.542 cm.	0.533 cm.
	4	1.833 cm.	1.000 cm.
	5	0.667 cm.	0.483 cm.
	1	1.800 cm.	0.863 cm.
	2	2.967 cm.	1.300 cm.
B	3	1.367 cm.	2.250 cm.
	4	0.304 cm.	0.100 cm.
	5	1.183 cm.	1.267 cm.

APPENDIX D

CHART REPRESENTING THE RESULTS OF THE MEASUREMENTS OF THE AMPLITUDES OF THE SEMITENDINOSUS, SWING PHASE FOR GROUP A AND GROUP B

Group and Subject		Right Leg	Left Leg
	1	1.167 cm.	0.667 cm.
	2	1.717 cm.	1.833 cm.
A	3	1.200 cm.	1.550 cm.
	4	0.850 cm.	1.783 cm.
	5	2.833 cm.	1.050 cm.
	1	1.333 cm.	1.183 cm.
	2	2.183 cm.	2.417 cm.
B	3	1.333 cm.	1.500 cm.
	4	1.442 cm.	1.008 cm.
	5	0.467 cm.	1.050 cm.

APPENDIX E

CHART REPRESENTING THE RESULTS OF THE MEASUREMENTS OF THE AMPLITUDES OF THE SARTORIUS, STANCE PHASE FOR GROUP A AND GROUP B

Group	and Subject	Right Leg	Left Leg
	1	0.983 cm.	0.500 cm.
	2	1.000 cm.	0.421 cm.
A	3	0.433 cm.	0.717 cm.
	4	1.383 cm.	0.500 cm.
	5	0.833 cm.	0.817 cm.
	1	0.692 cm.	0.383 cm.
	2	1.610 cm.	1.583 cm.
B	3	0.667 cm.	0.500 cm.
	4	0.300 cm.	0.100 cm.
	5	0.417 cm.	0.667 cm.

APPENDIX F

CHART REPRESENTING THE RESULTS OF THE MEASUREMENTS

OF THE AMPLITUDES OF THE SARTORIUS, SWING

PHASE FOR GROUP A AND GROUP B

Group and Subject		Right Leg	Left Leg
	1	0.842 cm.	0.917 cm.
	2	0.683 cm.	0.475 cm.
A	3	0.350 cm.	0.708 cm.
	4	0.500 cm.	0.533 cm.
	5	0.333 cm.	0.300 cm.
	1	1.166 cm.	0.250 cm.
	2	2.933 cm.	1.967 cm.
B	3	0.267 cm.	0.300 cm.
	4	0.100 cm.	0.333 cm.
	5	0.667 cm.	0.750 cm.

APPENDIX G

CHART REPRESENTING THE RESULTS OF THE MEASUREMENTS OF THE AMPLITUDES OF THE GLUTEUS MAXIMUS, STANCE PHASE FOR GROUP A AND GROUP B

Group and Subject		Right Leg	Left Leg
	1	0.583 cm.	0.600 cm.
	2	0.275 cm.	1.000 cm.
A	3	1.042 cm.	0.500 cm.
	4	1.150 cm.	1.917 cm.
	5	0.450 cm.	0.333 cm.
	1	1.208 cm.	0.500 cm.
	2	0.750 cm.	0.967 cm.
B	3	0.700 cm.	0.800 cm.
	4	0.500 cm.	0.592 cm.
	5	0.300 cm.	0.875 cm.

APPENDIX H

CHART REPRESENTING THE RESULTS OF THE MEASUREMENTS OF THE AMPLITUDES OF THE GLUTEUS MAXIMUS, SWING PHASE FOR GROUP A AND GROUP B

Group and Subject		Right Leg	Left Leg
	1	0.367 cm.	0.583 cm.
	2	1.208 cm.	1.500 cm.
A	3	1.583 cm.	0.842 cm.
	4	0.702 cm.	0.950 cm.
	5	0.717 cm.	0.333 cm.
	1	0.667 cm.	0.500 cm.
	2	1.167 cm.	1.333 cm.
B	3	0.233 cm.	0.750 cm.
	4	0.500 cm.	0.433 cm.
	5	1.042 cm.	1.875 cm.

APPENDIX I

CHART REPRESENTING THE RESULTS OF THE MEASUREMENTS OF THE AMPLITUDES OF THE GLUTEUS MEDIUS, STANCE PHASE FOR GROUP A AND GROUP B

Group and Subject		Right Leg	Left Leg
	1	0.500 cm.	0.625 cm.
	2	0.667 cm.	0.250 cm.
A	3	0.250 cm.	0.000 cm.
	4	1.267 cm.	0.867 cm.
	5	0.783 cm.	0.833 cm.
	1	3.083 cm.	0.950 cm.
	2	1.933 cm.	1.300 cm.
B	3	1.750 cm.	1.667 cm.
	4	0.583 cm.	0.650 cm.
	5	0.500 cm.	1.433 cm.

APPENDIX J

CHART REPRESENTING THE RESULTS OF THE MEASUREMENTS OF THE AMPLITUDES OF THE GLUTEUS MEDIUS, SWING PHASE FOR GROUP A AND GROUP B

Group and Subject		Right Leg	Left Leg
	1	0.500 cm.	0.967 cm.
	2	1.298 cm.	0.583 cm.
A	3	0.575 cm.	0.675 cm.
	4	2.017 cm.	1.417 cm.
	5	0.783 cm.	0.833 cm.
	1	2.000 cm.	0.417 cm.
	2	2.467 cm.	1.667 cm.
B	3	1.383 cm.	1.667 cm.
	4	0.192 cm.	0.583 cm.
	5	0.583 cm.	0.708 cm.

ABSTRACT

The purpose of the study was to determine through electromyography whether a non-pathological fault, such as lateral asymmetry at the pelvic level, would hinder, in significant manner, efficient functioning of the body.

A review of the literature revealed that although previous experiments had been conducted to determine the effects certain postural deviations had on the normal, efficient functioning of the body and that previous experiments had been conducted to determine which muscles performed which task as related to walking, none dealt with the specific effects of lateral deviations at the pelvic level on the upper leg muscles used in walking.

In this study twenty-five female students were screened to determine whether or not they demonstrated one half inch lateral deviation at the pelvic level. On the basis of the results of the screening session five test subjects and five reference subjects were selected. Electromyograms of five muscles (the biceps femoris, the semitendinosus, the sartorius, the gluteus maximus, and the gluteus medius--stance phase and swing phase of each) were taken. Amplitudes for the action potentials of each of the five muscles of the five test subjects and five reference subjects were computed. The results were compared between the two groups by the two-way analysis of variance statistical method. Girth measurements and strength measurements for the right and left leg of each subject were taken and then the results of the test group were compared with those of the reference group.

The conclusions arrived at, within the limitations of the study, were: (1) lateral asymmetry has no effect on the difference of strength measurements and girth measurements between the right and left leg of subjects with lateral asymmetry and subjects without lateral asymmetry, and (2) the data collected for the study fail to provide enough difference (since only one phase of one muscle demonstrates an important amount of difference between groups) to warrant rejection of the null hypothesis. Therefore, the statement that there would be no difference in the action potentials of certain muscles in the upper leg of subjects with lateral asymmetry recorded electromyographically while the subject walked on a treadmill when compared with similar recordings of the muscle action potentials of the subjects with no lateral asymmetry of the pelvis must stand.

Further research concerning the effect of specific postural deviations on the normal functioning of the human body as related to physical education should be encouraged.

VITA

S. Marie Landmesser

She was born in Munich, Germany on April 9, 1948. At the age of five she emigrated with her family to Toronto, Ontario, Canada. While attending David and Mary Thomson Collegiate in Scarborough, Ontario, she became interested in gymnastics and field hockey. Besides competing in gymnastics and track and field she served as the captain of the field hockey team for two years.

In the fall of 1967, she entered the School of Physical and Health Education at the University of Toronto. While attending the University of Toronto, she was a member of the W.I.T.C.A. Championship field hockey team for three years. She was also the Treasurer of the Physical and Health Education Women's Undergraduate Athletic Association, a writer of women's sports articles for the "Varsity" newspaper, and in her senior year she served as the editor of the School of Physical and Health Education Annual.

Outside of her university activities, she was employed as the assistant coach of the Brockton Gymnastics Club and was a member of the Kalev School of Modern Gymnastics. During the summers she was employed by the Ontario Government as a clerk with the Health Insurance Registration Board.

After graduating from the University of Toronto in 1971, she journeyed to Charleston, Illinois to take up the post of Graduate Assistant at Eastern Illinois University. While attending Eastern she became a member of the Midwest Association for Physical Education of College Women and an associate member of Delta Psi Kappa. She expects to complete all the requirements for the degree Master of Science in Physical Education by November, 1972.

She has since accepted a temporary position as an instructor in the Department of Physical Education at the University of Northern Iowa, Cedar Falls, Iowa.