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Electromyographic Comparison of Internal and External Obliques Using a Modified Version of Kendall's Strength Test Positions for Upper and Lower Abdominals

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ELECTROMYOGRAPHIC COMPARISON OF INTERNAL AND EXTERNAL OBLIQUES USING A MODIFIED VERSION OF KENDALL'S STRENGTH TEST POSITIONS FOR UPPER AND LOWER ABDOMINALS

By

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THESIS

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Abstract

The purpose of this study was to examine the activity of the internal obliques (upper abdominals) versus the external obliques (lower abdominals) during a modified version of Kendall's upper and lower abdominal strength tests using surface electromyography on adults. The study was not correlated to Kendall's theory due to the necessity to have the internal oblique electrode placed on the anterior abdomen. Twenty-four women and sixteen men participated in the study. All subjects were taught two positions ("easy and "hard") for both abdominal tests and performed eight trials. A normalized ratio was generated by dividing one "hard" trial by the mean of three "easy" trials for each position. A t-test revealed no significant difference between the activity of the external and internal oblique muscles in the two modified tests. There were no direct conclusions made regarding Kendall's abdominal tests. In conclusion, further research is needed with appropriate electrode placement on the lateral abdomen to examine muscle activity in Kendall's test positions for the upper and lower abdominals.

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Last, but surely not least, we wish to thank Helesia Witkowski and Nathan Currier-Groh for their support and encouragement throughout this endeavor.

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PREFACE

Definitions of Terms

action potential--is a term to describe a wave of electrical impulses caused by a change in the cell membrane permeability to ions. The action potential is a rapid depolarization and repolarization of the cell membrane precipitating a series of events in the muscle fibers that leads to a contraction (NIOSH, 1992).

agonist--is a muscle that contracts to produce a movement pattern (Prentice, 1994).

antagonist--is a muscle that is stretched as a result of opposing another contracting muscle (Prentice, 1994).

anterior superior iliac spine (ASIS)--is an anatomical term to describe a landmark located on the most anterior and superior bony prominence on the ilium (Netter, 1991).

artifact--is a term that describes false signals recorded by electromyography. Artifacts are generated by: movement of the electromyograph cables, movement between the electrode interface and skin, extraneous environmental electrical fields, and the electromyograph apparatus (NIOSH, 1992).

bipolar electrode configuration--is a phrase that describes an electrode placement in which two electrodes are placed over the target muscle and a third electrode is placed as a ground electrode in a neutral site (NIOSH, 1992).

critical value--is a term to describe the value that defines a statistically significant result at the set alpha level (Portney & Watkins, 1993).

crosstalk--is a term to describe unwanted myoelectric signals that are picked up from adjacent muscles (NIOSH, 1992).

degrees of freedom (df)--is a statistical concept indicating the number of values within a distribution that are free to vary, and is determined by *n* minus one where *n* equals the number of pairs of scores (Portney & Watkins, 1993).

easy leg-lowering (E-LL)--is a term to describe a modified position of Kendall's "fair+" grade for the lower abdominal strength test. The subject is supine with the arms folded across the chest and maintains the low-back flat on the table. The examiner guides the subject in lowering the legs to sixty degrees of hip flexion with the knees locked. The subject is asked to hold the position without assistance.

easy trunk-curl (E-TC)--is a term used to describe a modified position of Kendall's "fair" grade for the upper abdominal strength test. The subject is supine with forty-five degrees of shoulder flexion from the horizontal and the low-back flat on the table. The examiner guides the subject in raising the shoulders off the table while maintaining maximal thoracic spine flexion and maintaining the lower extremities on the table. The subject is asked to hold the position without assistance.

electrodes--is a term describing the receiving end of the EMG machine for the myoelectric signal (NIOSH, 1992). The surface electrodes are two small metal discs made of silver or silver chloride, 0.4-0.94 centimeters in diameter, with a cable attached to an amplifier that are placed on the skin overlying a muscle (Winters, 1990). Indwelling or fine-wire electrodes are placed directly into the muscle (Winters, 1990).

electromyography (EMG)--is a term describing the measurement of muscle activity, received by an electrode, which represents the response from multiple motor units during a muscle contraction. The EMG directly measures the amount of muscle activity, and is used to make inferences regarding muscle recruitment (Perry, 1992).

goniometer--is a tool used to measure the range of motion or position of a joint (Norkin & White, 1985).

hard leg-lowering (H-LL)--is a term that describes a modified position of Kendall's "good-" grade for the lower abdominal strength test. The subject is supine with the arms folded across the chest and maintains the low-back flat on the table. The examiner guides the subject to forty-five degrees of hip flexion with the knees locked. The subject is asked to hold the position without assistance.

hard trunk-curl (H-TC)--is a term that describes a modified position of Kendall's "good" grade for the upper abdominal strength test. The subject is supine with the arms folded across the chest and with the low-back flat on the table. The examiner guides the subject in raising the shoulders off the table while maintaining maximal thoracic spine flexion and maintaining the lower extremities on the table. The subject is asked to hold the position without assistance.

integrated electromyogram--is a processed record from the electromyograph of the muscle activity for a segment of time, measured in microvolt seconds or millivolt seconds, commonly calculated as the area under the curve (NIOSH, 1992).

isometric contraction--is a type of muscle contraction where there is an increase in muscle tension without a change in muscle length or joint angle (NIOSH, 1992).

lower abdominals--is the term referring to the rectus abdominis plus the lateral fibers of the external oblique (Kendall, McCreary, & Provance, 1993).

manual muscle test--is the technique of determining the strength of muscles using such known controls as the force of gravity and the application of manual resistance (Gonella, 1954).

microvolt second (μV)(s)--is a unit of measurement used by the EMG that equals one one-millionth of a volt per second.

motor unit--is a term that describes the smallest neuromuscular unit consisting of a single alpha motor neuron, it's neuromuscular junction, and all the muscle fibers innervated by it's axon (NIOSH, 1992).

motor unit action potential (MUAP)--is a name for the spatio-temporal summation of all individual muscle fiber action potentials of a motor unit (NIOSH, 1992).

muscle grade--is an expression of an examiner's assessment of the strength or weakness of a muscle or muscle group (Kendall et al., 1993).

muscle strength--is the sum of sarcomere force and fibrous tissue tension (Perry, 1992).

myoelectric signal--is a term to describe the spatio-temporal summation of all motor units within the recording area of an electrode (NIOSH, 1992). The myoelectric signal is regarded as an indirect measure of motor recruitment and a direct measure of muscle activity (NIOSH, 1992).

normalization--is a process to establish a standard of reference using a subject's integrated EMG results due to the variations that exist between individuals, such as, changes in tissue properties, differences in motor units (Perry, 1992). Normalization of the EMG signal is essential before comparisons between muscles, individuals, and trials can take place (NIOSH, 1992).

paired t-test--is a statistical test to compare the differences in scores or means within pairs so that subjects are compared only with themselves or their match (Portney & Watkins, 1993).

probability value (p-value)--is an arbitrary criterion or a demarcation on a line of probability between chance and reality that the null hypothesis is true (Portney & Watkins, 1993). If the p-value is greater than the set alpha level the null hypothesis is accepted and the risk of a type I error exists (Portney & Watkins, 1993).

recruitment--is the term to describe when the demand for an increase in muscle tension results in activation of motor units (NIOSH, 1992).

skin-fold caliper--is a device to measure subcutaneous fat on the human body. A fold of skin is grasped firmly between thumb and forefinger. The fold is measured with pincer jaws at a constant tension of 10 grams/squared millimeters. The thickness is recorded within two seconds from application of the calipers (McArdle, Katch & Katch, 1991).

synergist muscle--is a term to describe a muscle which is working with a target muscle to produce a greater force (Smith, Davis & Dennerll, 1991).

test-statistic (t-statistic)--is a ratio that reflects the relationship of the between-group and the within-group variance components. To reject a null hypothesis the t-statistic must be greater than or equal to the critical value (Portney & Watkins, 1993).

type I error--is a term used to describe when the null hypothesis is falsely rejected, or the alternative hypothesis is falsely accepted (Portney & Watkins, 1993).

type II error--is a term used to describe when the null hypothesis is falsely accepted, or the alternative hypothesis is falsely rejected (Portney & Watkins, 1993).

upper abdominals--is a term referring to the rectus abdominis plus the lateral fibers of internal oblique (Kendall et al., 1993).

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CHAPTER 1

INTRODUCTION

Background to Problem

Florence and Henry Kendall are considered pioneers in the development and refinement of techniques for manual muscle testing and the in-depth analysis of posture. Their techniques are based on clinical experience and understanding of functional anatomy. The Kendalls' techniques have extensive influence on physical therapy education and practice. Their book, *Muscles: Testing and Function, Fourth Edition*, hereinafter referred to as "Kendall," is one of the core texts used in physical therapy curricula throughout the United States.

Although Kendall's techniques and manual muscle test positions are widely used and clinically accepted, their method for differentiating the upper and lower abdominals has not been verified (see Appendix A for the description and techniques to test Kendall's upper and lower abdominal strength tests).

Kendall recommends looking closely at swayback and lordotic postures for possible stretch weakness of the abdominal muscles (Kendall, McCreary, & Provance, 1993). Some individuals test very strong in one of the abdominal tests but weak in the opposite test, that is, abdominal curl sit-up versus supine bilateral leg-lowering (Kendall et al., 1993).

Kendall defines the upper abdominals as the rectus abdominis plus the lateral fibers of the internal oblique (Kendall et al., 1993). The lower abdominals are defined as the rectus abdominis plus the lateral fibers of the external oblique (Kendall et al., 1993).

The obliques are fan-shaped muscles that help stabilize the trunk and pelvis, and span from the upper to the lower abdominal region. The origins and insertions of the muscle fibers are multidirectional and function differently depending on the muscle fiber orientation and type of trunk motion (see Appendix B) (Kendall et al., 1993). Therefore, the terms upper and lower abdominals do not refer to a compartmental separation, but rather to a functional differentiation.

Kendall postulates that the abdominal curl sit-up and supine bilateral leg-lowering test positions differentiate, respectively, between upper and lower abdominal strength. The internal oblique is thought to be more active than the external oblique in the upper abdominal test. Conversely, the external oblique is thought to be more active than the internal oblique in the lower abdominal test. There is a need to test these assumptions since accurate assessment of muscle strength or muscle imbalance is critical for thorough patient evaluation and subsequent treatment planning (Guffy & Burton, 1991).

Problem Question

Does a modified version of Kendall's upper and lower abdominal strength test differentiate the recruitment of the internal and external obliques as measured by using surface electromyography (EMG) on normal healthy adults?

Aims/Purpose

The focus of this thesis was to quantify and compare the muscle activity of the internal and external obliques using two modified versions of Kendall's strength tests.

The two remaining abdominal muscles, the rectus abdominis and transversus abdominis, were not measured. The rectus abdominis was not measured because it was considered to be active in both abdominal strength tests. The transversus abdominis was not measured because it was deep to the internal oblique and difficult to access with surface EMG and because it was not considered essential for the upper and lower abdominal tests.

Kendall's abdominal strength tests were defined as dynamic movements which was difficult to analyze with surface EMG and beyond the scope of this study. Therefore, a modified isometric version for each test was used to generate EMG readings for analysis. This study was also designed to be a catalyst for further EMG research and validation of Kendall's test positions.

CHAPTER 2

REVIEW OF LITERATURE AND CONCEPTUAL FRAMEWORK

Related to Manual Muscle Strength Testing

Manual muscle testing was first developed by Dr. Robert Lovett in 1912 as "gravity testing" to address infantile paralysis and has subsequently been refined by numerous physical therapists and physicians (Guffy & Burton, 1991). The strength of muscles has since been assessed using manual muscle testing with controls, such as, the force of gravity and the application of manual resistance (Gonella, 1954). Manual muscle strength testing has been shown to address the function of muscle groups, and the ability to provide stability and support for the human body (Kendall et al., 1993).

In 1961, Smith, Iddings, and Spencer created a numerical muscle strength index of 1-5 that is used today (Daniels & Worthingham, 1986). Their index equates to Kendall's grading of 1-10, or Kendall's descriptive grading of "trace," "poor," "fair," "good," and "normal."

Several articles and texts have detailed the positive and negative attributes of manual muscle testing, including Daniels and Worthingham (1986), Guffy and Burton (1991), and Kendall et al. (1993). One of the advantages of manual muscle testing has been how readily it can be performed once an examiner develops the necessary expertise and practical experience (Kendall et al., 1993). Manual muscle testing has also been considered advantageous because it does not require any equipment, reduces patient anxiety, differentiates muscles precisely, decreases muscle substitution, and allows a variety of muscles to be tested (Guffy & Burton, 1991; Kendall et al., 1993).

The grading system has been shown to be accurate and objective for the "trace," "poor," "fair," and "fair+" grades (Kendall et al., 1993). Moderate to high reliability of manual muscle testing using gross grades for muscle strength, that is, "trace" to "normal" has been demonstrated. One study of muscles grades has shown a 71 percent agreement for all muscle grades and a 93 percent agreement within one full muscle grade (Iddings, Smith, & Spencer, 1961).

The disadvantage of manual muscle testing has been primarily due to the subjectivity of the examiner's assessment of "good" and "normal" muscle grades (Guffy & Burton, 1991). The examiner's skill with manual muscle testing influences greatly the validity of the muscle grades. Kendall has emphasized the need for the examiner to fixate the body as a whole, stabilize the part proximal to the tested part, use the correct test position, and use the correct direction of pressure or resistance (Kendall et al., 1993; F. P. Kendall, personal communication, July 8, 1995).

Manual muscle testing has also been unable to measure differences within the higher ranges of strength, which makes it difficult to use for research purposes involving athletes (Guffy & Burton, 1991). Isokinetic machines have been an alternative to manual muscle testing to quantify the higher strength ranges and more accurately assess activity-specific strength (Guffy & Burton, 1991). Research has shown isokinetic machines to generate precise objective measurements against resistance and through a full range of motion (Guffy & Burton, 1991). However, the risk exists that the isokinetic results have been based on inaccurate subject positioning and stabilization (F. P. Kendall, personal communication, July 8, 1995).

Related to Abdominal Muscle Activity

Kendall has observed that when the subject raises the head and shoulders during the upper abdominal test, the chest is pulled toward the pelvis primarily by the action of the rectus abdominis (Kendall et al., 1993). EMG research has shown that the rectus abdominis is most active during head raising, but the shoulders must lift off the floor to get significant activity of the obliques (Floyd & Silver, 1950). As the subject continues Kendall's trunk-curl sit-up, the ribs flare outward and the infrasternal angle increases by the action of the internal oblique's lateral fibers (Kendall et al., 1993). Kendall has proposed that the moment hip flexion begins is when the greatest resistance against the internal oblique takes place (F. P. Kendall, personal communication March 7,1996). When the trunk-curl is completed and the hip-flexion phase begins, the infrasternal angle has been observed to decrease by the action of the external oblique's anterior fibers (Kendall et al., 1993).

In order for a subject to perform the lower abdominal test, Kendall has observed that the pelvis must be stabilized in a posterior tilt (Kendall et al., 1993). The posterior tilt has been thought to be accomplished by the rectus abdominis' upward pull on the pubis, and the external oblique's lateral fibers pulling on the anterior iliac crest in a superior and posterior direction (Kendall et al., 1993). In one study, the external oblique and rectus abdominis were shown to have the strongest activity in straight leg-raising (Flint & Gudgel, 1965). Another study has shown that all abdominal muscle groups were active during bilateral leg-raising (Floyd & Silver, 1950).

Past abdominal strength research has focused primarily on movements that challenge the abdominals using straight-plane variations of the sit-up and leg-raising (Lipetz & Gutin, 1970; Flint & Gudgel, 1965; Floyd & Silver, 1950). Of the four abdominal muscles, the muscle activity of the rectus abdominis and external oblique have been measured most often (Lipetz & Gutin, 1970; Flint & Gudgel, 1965).

Research for the internal oblique has been minimal. Floyd and Silver (1950), have found that the internal and external obliques contract with a force equal to the effort exerted when the subjects strain or hold their breath. A more recent study that assessed trunk rotations in standing has shown the obliques to be active in rotational movements of the trunk (Marras & Mirka, 1992).

Related to Electrode Placement

Studies have chosen surface electrode sites based on minimizing the recording of non-targeted muscles (Hughes, Chaffin, Lavender, & Anderson, 1993). A common anterior electrode placement for the internal oblique has been at a triangular region deep to the external oblique aponeurosis (Basmajian, 1974; Floyd and Silver, 1950; Turker, 1993). The placement was shown to be bounded by the rectus abdominis, the inguinal ligament, and a line drawn from the anterior superior iliac spine (ASIS) to the umbilicus (Floyd and Silver, 1950).

The anterior placement records the activity of the internal oblique's transverse fibers. Kendall speculates that the action of the transverse fibers act to pull the lower abdomen inward and not flex the trunk due to the origin and insertion of the fibers (Kendall et al., 1993). Kendall has proposed that previous studies may have inaccurately assessed the activity of the internal oblique in spine flexion (F. P. Kendall, personal communication, July 6, 1995).

For accurate recording of the internal oblique during the upper abdominal test, Kendall has suggested placing the electrodes on it's lateral fibers (F. P. Kendall, personal communication, July 6, 1995). Anatomical studies have determined that the internal oblique spans the anterior two-thirds of the iliac crest (Kendall et al., 1993). One-sixth of this area (moving posteriorly from the midline in the sagittal plane) has been shown to not be overlapped by the external oblique (F. P. Kendall, personal communication July 6, 1995).

One study used the area of the internal oblique that was not overlapped by the external oblique, also known as the lumbar triangle of petit (Marras & Mirka, 1992). The lumbar triangle of petit has been shown to be bounded by the thoracolumbar fascia, iliac crest, and external oblique with the apex below the 12th rib (Netter, 1991). Marras and Mirka (1992) have questioned the results from the internal oblique, due to the possibility of crosstalk from latissimus dorsi when measured at the lumbar triangle of petit.

The external oblique, being more superficial, has been considered easier to access with surface EMG electrodes. One placement has been along an oblique line above the anterior one-half of the iliac crest (Floyd & Silver, 1950; Turker, 1993). A second electrode site for the lateral external oblique fibers has been along the costal margin in an oblique line below the ninth rib (Flint & Gudgel, 1965).

Kendall has stated that the lateral external oblique fibers have been chiefly involved with lower abdominal pelvic stabilization during leg-lowering (Kendall et al, 1993). Therefore, Kendall has recommended that electrodes be placed above the anterior one-half of the iliac crest (F. P. Kendall, personal communication, July 6, 1995).

Related to Electromyography

Electrophysiology of Muscle

A series of electrophysiological events have been shown to occur when muscle fibers contract. The smallest neuromuscular unit that defines the electrophysiological event is called a motor unit. A single motor unit has been described as an alpha motor neuron, its neuromuscular junction, and all the muscle fibers it innervates (NIOSH, 1992).

A motor unit innervates many muscle fibers and has been shown to create asynchronous muscle fiber activity (Floyd & Silver, 1950). The axon branches have been found to differ in size and length resulting in different velocities of conduction for different muscle fibers (Winter, 1990). The electrical impulse traveling through the motor unit is called the action potential (NIOSH, 1992).

Research has determined that initially the central nervous system initiates an action potential in the motor neuron. Next, the action potential has been shown to conduct an electrical impulse down the axon to the muscle fibers motor end-plate. At the end-plate, studies have shown that the chemical acetycholine is released, which stimulates a change in muscle cell permeability to sodium ions. The propagation of the electrical impulse through the muscle cells is assisted by T-tubules, thus ensuring a nearly simultaneous contraction of the entire muscle fiber. The sum of the muscle fiber action potentials constitute a motor unit action potential (NIOSH, 1992).

A pair of EMG electrodes have been shown to detect polarity differences resulting from the repolarization and depolarization of the action potential as it travels through the muscle fiber (Winter, 1990). Two monophasic waves have been seen as a record of the action potential traveling under one electrode and then traveling under the other electrode, that is, one above the baseline, and one below the baseline (NIOSH, 1992). The time span between the two waveforms has been determined to depend on the velocity of the action potential and the distance between the two electrodes (NIOSH, 1992).

The depolarization and repolarization waves result in an increase or decrease of the EMG amplitude and affect the shape of the waveform (NIOSH, 1992). The resulting amplitude and waveform have been shown to be influenced by muscle function variables and EMG recording variables (NIOSH, 1992).

Muscle Function Variables

The EMG signal has been shown to be influenced by the following muscle function variables: (1) motor fiber recruitment, (2) muscle fatigue, (3) isometric versus dynamic tension, (4) muscle length changes, (5) agonist and antagonist muscle interaction, and (6) crosstalk from adjacent muscles.

The amplitude and shape of an EMG recording has been found to differ depending on the type of motor fibers recruited (NIOSH, 1992). Research has shown that when graduated demand is placed on a muscle an increasing number of motor units are recruited and/or the available motor units firing frequency increases, resulting in larger EMG amplitudes (NIOSH, 1992). Recruitment of muscle fibers has been shown to begin with slow, small, fatigue-resistant motor units commonly found in postural muscles (NIOSH, 1992). Further recruitment results in activation of larger, faster, fatigueable motor units, commonly used for rapid or power movements (NIOSH, 1992).

When muscle fibers cannot meet prolonged demands placed on them, fatigue results and the EMG signal has been shown to vary (Winter, 1990). EMG recording of fatigued muscle fibers have been shown to exhibit more synchronous firing of motor units and a decrease in higher frequency components of the MUAP (Winter, 1990). With muscle fatigue, the velocity of the MUAPs has been shown to decrease resulting in a longer signal duration resulting in an increase in EMG output (Winter, 1990).

The third muscle function variable that influences the EMG output relates to muscle tension--isometric and dynamic. Early research demonstrated a linear relationship between isometric muscle contraction and millivolt output (Lippold, 1952). Woods, Bigland, Ritchie (1983), and Lawrence and DeLuca (1983), have shown that the relationship between force and EMG output is dependent upon muscle fiber composition. Uniform fiber composition has shown a more linear relationship, while fibers with a mixture of small and large motor units have shown a non-linear relationship (NIOSH, 1992). Other studies have shown a nonlinear or curvilinear relationship with muscles tested at different lengths (Winter, 1990).

Dynamic muscle tension has been defined as occurring during either concentric or eccentric muscle contractions. There are limited studies related to dynamic muscle tension and EMG output. One study with concentric contractions was done by Bigland and Lippold (NIOSH, 1992). Their study showed that if the demand on the muscle is represented as a function of velocity, with constant EMG levels, the dynamic tension can be seen to demonstrate a linear relationship similar to an isometric contraction (NIOSH, 1992). Another study has shown that eccentric contractions produce greater EMG signals than concentric contractions (NIOSH, 1992).

The relationship between EMG amplitude and force at different muscle lengths has been investigated. Past EMG studies have shown a nonlinear or curvilinear relationship with muscles tested isometrically at different lengths (Winters, 1990). Contrary to Winter's study, two studies by Komi have demonstrated that EMG amplitude does not significantly change with muscle length changes (Winter, 1990). These relationships have allowed the EMG to be used to make inferences about force output if muscle length is not changing rapidly (Winters, 1990).

Antagonist muscle activity recorded by the EMG has been shown to create false signals for the target muscle. Synergists and antagonist muscles have been shown to be recruited depending on the need for movement or stability (Prentis, 1994). Past EMG research was based on the assumption that little or no antagonist muscle activity took place during isometric muscle contractions (NIOSH, 1992). New research has demonstrated that antagonist and synergistic muscle activity is present when the target muscle is showing low-level EMG activity (Perry, 1992).

Crosstalk represents unwanted EMG muscle activity from non-targeted, adjacent muscles. When crosstalk occurs the EMG signal has been shown to blur the onset and cessation time of the target muscle and create a noisy baseline. Surface electrodes have been shown to detect MUAP's close to the electrode without crosstalk unless the target muscle is very small (Winter, 1990). Research has demonstrated that isolating the target muscle is necessary to limit the recording of antagonist activity and reduce the possibility of crosstalk (Winters, 1990).

Based on the literature review, the effects of the muscle function variables are applicable to an EMG study of the obliques. The obliques are considered to be superficial, large fan-shaped muscles with uniform fiber composition comprised of primarily the slow-firing fiber type. Muscles with slow-firing fiber type are more resistant to fatigue and muscles with uniform fiber composition demonstrate a linear relationship between muscle activity and EMG output.

The muscle function variables for an EMG study are also considered in the study design. The use of isometric muscle contractions for analysis of the obliques establishes a theoretical linear relationship between the muscle activity and EMG output. The literature supports the theory that a linear relationship also applies when two different isometric muscle length positions are used, such as two isometric abdominal strength positions. The potential for antagonist muscle recruitment is reduced when the target muscle is isolated as much as possible. The test design for the obliques that includes consistent test positioning with the low-back flat on the table helps to reduce the possibility of antagonist activity. The potential for crosstalk exists when measuring the obliques due to the overlap of the abdominal muscles on each other. Placing the electrodes out of signal range of adjacent muscles is crucial to decrease the effects of crosstalk.

Related to Recording of EMG Signal

The EMG recordings have been found to differ depending upon variables, such as: (1) placement of the electrodes; (2) type of electrode, that is, surface or fine-wire; (3) thickness of skin-fold; and (4) the need for amplification and the need to control unwanted signals ("artifact").

Placement of Electrodes

Research has shown ideal electrode placement is dependent upon the distance between the two electrodes and muscle fiber orientation. Contamination of the EMG signal has been shown to occur with wider spacing of electrodes (Perry, Easterday & Antonelli, 1981). Electrodes closely spaced have shown higher frequency components in the spectrum than widely spaced electrodes (Winter, 1990). Muscle selectivity and amplitude have been shown to be best balanced when the electrodes are placed one centimeter apart (Perry, 1992). Basmajian and Deluca have recommended that the electrode placement separation center-to-center should be between 2-10 mm (NIOSH, 1992).

Research has demonstrated that the electrodes should be placed parallel to the muscle fibers because readings of action potentials in directions perpendicular to the muscle fiber cannot be picked up (De la Barrera & Milner, 1994). Placing electrodes near the muscle belly has been shown to result in higher amplitudes than electrodes placed closer to the musculotendinous junction (Zuniga, Troung, & Simon, 1970). Another study has recommended placing electrodes at the motor-point, or midway between the muscle belly and distal tendon (Basmajian and Deluca, 1985).

Surface versus Fine-wire Electrodes

The choice between surface or fine-wire electrodes is dependent upon the research goals. Compared to fine-wire electrodes, surface electrodes record a larger muscle area (Perry, 1992). Placement of surface electrodes have shown the advantage of more effective and reproducible EMG results for superficial muscles compared to needle or fine-wire electrodes (Perry, 1992). Surface electrodes have been chosen over needle or fine-wire electrodes due to the preference of the subject and the comfort, and ease with which they can be applied by an investigator (Perry, 1992).

Some disadvantages of surface electrodes have been that the target muscle can move under the electrode resulting in recording different thicknesses of muscle tissue under the electrode (NIOSH, 1992). Surface electrodes, unlike fine-wire, lack the ability to precisely measure deep muscle or detect motor units in a very precise area (Perry, 1992). Surface electrodes have been shown to be less able to detect very small signals compared to fine-wire electrodes (Winter, 1990).

Studies have shown that the surface electrode will record any signals of varying intensities from the pick-up zone regardless of origin (Perry, 1992). Because of the generalizability of the recording, the possibility of crosstalk is higher with surface electrodes than with fine-wire electrodes (NIOSH, 1992). With either electrode choice, Winter (1990) has shown that only a fraction of all motor unit action potentials are recorded.

Skin-Fold Thickness

Skin acts as a low-pass filter attenuating higher frequencies of EMG signal. Consequently, the frequency ranges recorded by surface EMG have been shown to be lower than those recorded by fine-wire EMG (Perry, 1992). One study compared surface EMG sensitivity for skin-fold thickness in the ranges of 2-4 millimeters (mm), 9-11 mm, and 19-21 mm (De la Barrera & Milner, 1994). The researchers observed that surface EMG sensitivity to the electrical stimulation of muscles diminished as the subcutaneous fat increased (De la Barrera & Milner, 1994). At the other extreme, if the subcutaneous layer was too thin, that is, 2-4 mm, then the surface EMG was less capable of representing a surface muscle and overall activity (De la Barrera and Milner, 1994).

Amplification Versus Control of Noise

Amplification, or "gain" has been shown to be necessary to increase the raw EMG signal to a usable level (NIOSH, 1992). A gain of two has been shown to be sufficient in picking up small signals and is necessary for a workable EMG value (Winter, 1990). The risk exists that too much amplification may allow unnecessary artifact in the final signal.

Artifact has been shown to be minimized by limiting the frequency range and avoiding unnecessary signals. The myoelectric signal has been shown to be influenced by power lines at 60 Hz, components within the amplifier, and touching or moving the electrodes or cable at 0-10 Hz (Winters, 1990). Most of the myoelectric signals collected using surface EMG has been shown to occur in a range of 20-200 Hz (Winter, 1990). Therefore, because of the Nyquist frequency rule, myoelectric signals have usually been collected at 400-500 Hz for surface EMG and up to approximately 2000 Hz for wire electrodes (Perry, 1992).

Processing of the EMG

Several steps have been shown to be necessary to transform the raw signal into a usable format. Inverting and adding the negative amplitudes of the raw data to the positive amplitudes of the raw data has been defined as rectification of the wave;

and generates an absolute value of EMG activity in mV or µV (Perry, 1992).

Integration has been defined as the filtering of the rectified EMG signals in relation to time in millivolt-second (mV•s), which quantifies the area under the waveform (Winter, 1992). The area under the waveform has been shown to be proportional to motor unit amplitude, duration, and rate of firing (NIOSH, 1992). A variety of methods have been used to integrate full-wave rectified signals including: integration over the entire period of muscle contraction, over a fixed interval of time that is repeated, and to a preset level after which the integration cycle is repeated (Winters, 1990). The processed EMG data has been used as an absolute value or converted as a percent of a standard normalization (Perry, 1992).

Research has shown that the EMG signal can change from time to time due to changes in electrode placement, tissue temperature, and tissue properties (NIOSH, 1992). Therefore, normalization of the EMG signal has been considered essential before comparisons between muscles, individuals, and trials can take place (NIOSH, 1992). Normalization has been defined as a process of establishing a standard of reference using a subject's integrated EMG result (Perry, 1992). Past methods for normalization have used submaximum voluntary contractions or maximum isometric contractions as a reference EMG value (Perry, 1992; Turker, 1993; Winter, 1990).

Reliability of EMG

Reliability of the EMG has been controlled by the choice and spacing of electrodes, as well as the preparation of the recording site. However, reliability can be adversely effected by uncontrollable factors, such as, subject motivation, body composition, and anatomical variations (NIOSH, 1992).

The EMG signal associated with dynamic tension has not been shown to be as reliable as those signals from isometric contractions (Winter, 1990). Tension changes have been shown to be greater in eccentric contractions versus concentric contractions for the same muscle activation (Winter, 1990). Therefore, researchers have recommended that isometric contractions may most reliably represent the EMG-force relationship (NIOSH, 1992).

In 1952, Lippold showed high reliability coefficients of 0.93-0.99 for interday recordings when electrodes were not replaced between trials (NIOSH, 1992). Komi and Buskirk (1970) assessed the reproducibility of surface EMG at various muscle tensions over several test days. The reliability coefficients were above 0.85 for all muscle tensions. Multiple tests showed a reliability coefficient between 0.91 and 0.97 with good reproducibility. In 1985, Kadaba demonstrated, in gait measures, that surface electrodes had higher reliability than fine-wire (NIOSH, 1992).

Summary

There is an absence of studies regarding the validity of Kendall's abdominal strength tests. Numerous studies cite the activity of the upper and lower abdominals, but they have never delineated the upper from lower function as Kendall has proposed. Therefore, an EMG study to differentiate the muscle activity of the internal and external obliques during Kendall's abdominal strength test procedure is warranted.

The literature review supports the use of EMG for quantitative analysis of the muscle activity for the obliques. Past studies give credibility for intraday testing using: surface electrodes, isometric muscle contractions, a skin-fold parameter of 5-18 mm, rest periods of one minute between trials, and a submaximal muscle contraction to normalize the data.

Hypotheses

This study has two alternative hypothesis: (1) there is significantly more recruitment of the internal oblique, than the external oblique, during the trunk-curl test; and (2) there is significantly more recruitment of the external oblique, than the internal oblique, during the leg-lowering test. The following null hypothesis is tested: there is no difference between recruitment, as detected by surface EMG, of the external and internal oblique muscles when performing the trunk-curl and leg-lowering tests. The hypotheses are stated as:

(1) Ho: $\mu_D = 0$, there is no difference between the means;

(2) Ha_1: $\mu_D > 0$, internal oblique mean greater than external oblique mean during the trunk-curl; and

(3) Ha_2: $\mu_D < 0$, internal oblique mean less than external oblique mean during leg-lowering.

CHAPTER 3

METHODOLOGY

Initial Investigation

For the upper abdominal test, Kendall proposed that the critical muscle fibers to measure for EMG activity were the lateral fibers of the internal oblique. Since optimal electrode placement for the internal oblique was considered crucial, an attempt to measure its muscle activity was made during the pilot study. The electrode placement for the internal oblique lateral fibers was over the lumbar triangle of petit, parallel to the muscle fibers (Netter, 1991).

During the pilot study the triangle was palpated while the subject performed the abdominal curl sit-up. It was observed that the two vertical sides of the triangle appeared to approximate themselves. Therefore, there was a high probability of crosstalk from the latissimus dorsi and external oblique muscles using surface electrodes for the internal oblique on the triangle of petit.

Due to the possibility of crosstalk the electrode placement for the internal oblique was moved to an anterior location. It was recognized that the anterior placement would not directly measure the muscle activity of the lateral internal oblique fibers that are crucial to differentiating the upper and lower abdominals. But, due to the need to reduce the possibility of crosstalk and unavailability of fine-wire electrodes, the anterior placement was used.

Design

Study Site

The study site was the Grand Valley State University (GVSU) physical therapy therapeutic exercise laboratory located in Allendale, Michigan, with approval and supervision by Jim Scott BS, MA, PES and Gordon Alderink MS, PT. The physical therapy therapeutic exercise laboratory had a room with an examination table that was used for the test procedure. The Noraxon's Multichannel Myosoft/Myosystem 1200 EMG system with disposable silver/silver chloride electrodes was used to collect the raw data during the test.[1]

Design of Muscle Test

Kendall's upper and lower abdominal strength tests were modified to measure isometric EMG activity. Two static positions were designed for each abdominal test.

The easy trunk-curl (E-TC) was the term used to describe the modified position of Kendall's "fair-" grade for the upper abdominal strength test. The subject was supine with 45 degrees of shoulder flexion from the horizontal and with the low-back flat on the

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[1] *Noraxon USA Inc., 13430 North Scottsdale Road, Suite 106, Scottsdale, Arizona 85254*

table. The examiner guided the subject to raise the shoulders off the table while maintaining maximal thoracic spine flexion and maintaining the lower extremities on the table with the knees straight (see Appendix A, Kendall's Grading of the Upper Abdominal Muscles, Fair + (6) grade).

Hard trunk-curl (H-TC) was the term used to describe the modified position of Kendall's "good" grade for the upper abdominal strength test. The subject was supine with the arms folded across the chest and with the low-back flat on the table. The examiner guided the subject to raise the shoulders off the table while maintaining maximal thoracic spine flexion and maintaining the lower extremities on the table with knees straight (see Appendix A, Kendall's Grading of the Upper Abdominal Muscles, Good (8) grade).

Easy leg-lowering (E-LL) was the term used to describe the modified position of Kendall's "fair+" grade for the lower abdominal strength test. The subject was supine with arms folded across the chest and maintained the low-back flat on the table. The subject was directed to unilaterally raise the legs to 90 degrees of hip flexion. The examiner guided the subject to lower the legs to 60 degrees of hip flexion with the knees locked (see Appendix A, Kendall's Grading of the Lower Abdominal Muscles, Fair + (6) grade).

The hard leg-lowering (H-LL) term was used to describe the modified position of Kendall's "good-" grade for the lower abdominal strength test. The subject was supine with arms folded across the chest and maintained the low-back flat on the table. The examiner guided the subject to 45 degrees of hip flexion with the knees locked (see Appendix A, Kendall's Grading of the Lower Abdominal Muscles, Good - (7) grade).

All subjects were taught the "easy" and "hard" positions for both abdominal tests. Each subject performed three "easy" trials and one "hard" trial for each position. The subjects were required to hold a five-second isometric contraction independently for all of the trials. The sequence of the trials was determined by each subject randomly selecting eight cards where one trial was labeled on each card.

Electrode Placement

Two pairs of electrodes were placed on the right trunk in a bipolar electrode configuration. The electrodes remained in place throughout all trials in order to maximize reliability.

The electrode placement for the internal oblique was located by drawing a horizontal line from the right ASIS to the left ASIS. The first electrode center was placed two centimeters medial to the right ASIS and one centimeter distal to the horizontal line. The second electrode was placed five millimeters medial to the first electrode.

The external oblique electrode placement was found by drawing a line from the most inferolateral aspect of the right tenth rib, to the right ASIS. The length of the line was then divided in half to establish a midpoint. One centimeter posterior to the midpoint a mark was made and the first electrode was placed. The second electrode was placed five millimeters superior to the first electrode and parallel to external oblique fibers.

Sample

The sampling procedure was one of convenience and availability. The subjects were GVSU students, faculty, or affiliated with GVSU. All of the subjects volunteered to participate in the study.

Inclusion criteria to participate in the study were:

1. healthy adults (without a history in the last three years of abdominal or back surgery or current symptoms of abdominal or back problems, and no current illness),
2. skin-fold caliper measurement between 5-18 mm, taken at one-fingers width above the most superior aspect of the right iliac crest,

3. ability to bear weight on the forearms with the elbows at the side (in supine, with the pelvis resting on the table),

4. greater than or equal to 70 degrees of unilateral hip flexion with the knee straight, and

5. the ability to maintain the H-LL and H-TC positions independently for ten seconds.

Subjects who met the inclusion criteria were given instructions for proper clothing, test date, time, and location.

Instruments

EMG Instrumentation

The GVSU physical therapy therapeutic exercise laboratory was equipped with a Noraxon Myosystem 1200 Research EMG unit for raw data collection. A Myosoft computer package was used to analyze and process the raw data. The Myosoft program rectified and integrated the raw data. The program was able to isolate a three-second contraction interval and convert the raw data into text format for statistical analysis.

The Myosystem 1200 manual parameters chosen were use of 2 channels for raw data and 2 channels for integrated data, and a sampling frequency of 500 Hz. A filter range of 16-500 Hz, and a gain of 2 for amplification were also chosen. The electrode diameter was 5 mm.

Skin-Fold Caliper

A "Lange" skin-fold caliper was used to determine if the proposed subject fit into the inclusion criteria of skin-fold range within five to eighteen millimeters (De la Barrera and Milner, 1994). The subjects were measured on the lateral aspect of the right waist, one-fingers width above the most superior aspect of the iliac crest.

Goniometer

A standard manufactured goniometer was used to measure the amount of hip flexion for the prescreen test and during the E-LL and E-TC trials. Hip flexion was measured by aligning the arms of the goniometer with the subjects trunk and fibular head.

Procedures

Recruitment of Subjects

We approached members of the GVSU men's baseball team, woman's basketball team, and track team. The remaining subjects were recruited from the GVSU campus recreation center (see Appendix C).

Prescreen

The prescreen took place at two different GVSU sites: the physical therapy therapeutic exercise laboratory and the recreation center. Upon filling out the prescreen demographics, the subject was asked to take a few minutes to stretch out the hamstring muscles in their own preferred manner (see Appendix D). The subject then had the skin-fold test over the lateral abdomen. For the remainder of the screening, the subject was asked to lie supine on a thin mat. The subject was then asked to come up from supine and rest on the elbows to establish adequate trunk flexion. The subject's hamstring length was measured during a unilateral straight-leg raise. One examiner supported the subject's leg on the floor while raising the other leg. The second examiner palpated the subject's ASIS to note the beginning movement of the pelvis. The second examiner verbally instructed the first examiner to stop and hold. The second examiner then measured the hip angle with a standard goniometer placed over the subject's greater trochanter aligned with the subject's trunk and fibular head.

To prescreen for the subject's ability to hold the test positions for five-seconds without fatigue, the subject was asked to perform the H-TC and H-LL for 10 seconds. The subject received manual and verbal cues to achieve the position. The subject began the H-LL test by crossing the arms over the chest and pulling the knees toward the chest one at a time. Next, the subject was asked to note the feeling of the low-back on the floor and directed to maintain the trunk position. An examiner aligned the goniometer for 45 degrees of hip flexion and horizontally with the subject's trunk. The subject was directed to point the legs up towards the ceiling and lower the legs enough to straighten the knees. Next, the subject was asked to lower the straight legs to 45 degrees of hip flexion and hold the position. The examiner palpated the right ASIS to monitor the subject's ability to hold the position.

For the trunk-curl prescreen, the subject was asked to begin by crossing the arms over the chest and with the legs relaxed in a neutral position. The subject was asked to maximally curl the neck and thoracic spine to lift the shoulders off the floor, clearing the shoulder blades while maintaining the low-back and legs on the table.

As a motivation for prescreen participation, the subject was offered, for their own use, information regarding abdominal exercises. The subject was also given the manual muscle test results from the prescreen.

Pilot Study

The first pilot study was completed to gain familiarity with the EMG instrumentation, to become skilled in the test procedure, and to test the optimal placement of the electrodes. A second pilot study was performed with the internal oblique electrodes on the lateral fibers. The procedure for the pilot studies followed the same sequence that was later used for subject testing.

Reliability Study

A test-retest reliability study was performed to access reproducibility of the strength grade positions as measured using EMG. The EMG data from the 3 trials of the "easy" positions, that all the 40 subjects performed during the study, was used for reliability. A separate test-retest reliability study of the "hard" position was conducted with 5 subjects using the testing procedure from the study.

Subject Testing

Data collection took place at GVSU physical therapy therapeutic exercise laboratory in January and February 1996. The subjects read and signed the consent form before testing began (see Appendix E). Random selection of trial sequence was accomplished by the subjects picking index cards from a group of eight cards. The subjects were then directed to lay supine on a mat for skin preparation and electrode placement. Electromyographic data were collected while the subjects performed three E-LL and one H-LL, and three E-TC and one H-TC (see Appendix F). All subjects were given the same verbal instructions during data collection (see Appendix H).

For each trial, the subject was guided into position by one examiner and asked to "hold" the position. The second examiner then counted to five seconds with a stopwatch and directed the subject when to relax to allow for a five-second segment of data collection. The data endpoint was set when the subject finished holding a position for five seconds. Examiners used a stopwatch and created a data endpoint by striking return on the computer keyboard, which resulted in a cessation of EMG collection. An examiner monitored a one-minute rest for the subject while preparing the computer for the next trial. Upon completion of the eight trials, the subject was assisted in removal of the electrodes and thanked. The subject was offered a beverage and snack as a benefit for participation.

Potential Hazards

The potential hazards to the subjects were minimal. All the subjects were at risk for sustaining minor muscle strain or experiencing discomfort following the data collection. Some discomfort was also caused when the arms of the skin-fold calipers approximated for the abdominal skin-fold evaluation during the prescreen test.

Data Analysis

EMG Data Analysis

In order to interpret the raw EMG output, the data was rectified, integrated, segmented, and normalized. The myosoft EMG software rectified and integrated the raw signals of each trial.

Once the data was rectified and integrated, markers were placed within the middle of the rectified waveform to isolate one segment of the most consistent contraction. The Myosoft computer program was able to analyze the middle three seconds of a five second hold. This was accomplished by setting the end-marker at a one-second distance before the data endpoint. The beginning-marker was set at a three-second distance before the end-marker. The total integrated EMG for a three-second segment of muscle contraction was stored for later normalization and analysis (see Appendix F).

Normalization of the EMG data was required in order to make comparisons between individuals. The data was normalized by dividing the integrated EMG values of the trial for the H-TC or H-LL by the mean amplitude of three trials for E-TC or E-LL, respectively. This produced a "hard-easy" (HE) ratio for each trial (see Appendix G).

Statistical Analysis

The HE ratios were used to compare the differences between the muscles to see if they demonstrated a normal distribution. An apparent normal distribution of the mean differences was observed making the one-tailed paired t-test appropriate for determining statistical significance of the data (alpha level 0.05). The required assumptions that must be met to use the paired t-test have been defined as: the data must be normally distributed, and the subjects must be independent of one another, but not necessarily have independent variables within subjects (Portney & Watkins, 1993).

The stated hypotheses were unidirectional because the study attempted to test Kendall's assumption rather than look at variability of oblique muscle activity, consequently, the one-tailed paired t-test was used. The one-tailed paired t-test has been shown to be appropriate when the hypothesis predicts that one specific mean will be larger than the other (Portney & Watkins, 1993). The statistical packages of SPSS 6.1, SAS, and ICS were used for statistical data analysis.

Test-Retest Reliability Analysis

Three trials of test-retest of a test position were performed by each reliability subject in order to access the reproducibility of the strength grade positions, as measured using EMG. Window's program SAS was used to derive the reliability coefficient using the ICC formula model number three. The intraclass correlation coefficient (ICC), formula model number three, ICC = BMS - sEMS/EMS, was appropriate for assessing the mean of several measurements (Portney & Watkins, 1993). ICC represents intrarater reliability, BMS stands for mean square between, and EMS represents mean square error (Portney & Watkins, 1993). To analyze the reliability of the test positions, a coefficient above 0.75 has been shown to have good validity while a value above 0.90 ensures valid interpretation of results (Portney & Watkins, 1993). A reliability coefficient of 0.90 was considered appropriate for the study.

Anticipated Problems

The following problems were anticipated:

1. PROBLEM. Wrong electrode placement.

SOLUTION. Electrode placement was determined by anatomical landmarks as guides and the electrodes were consistently placed by the same researcher.

2. PROBLEM. Generation of artifact noise.

SOLUTION. Parameters of sixteen to five hundred Hz were chosen, a built-in filter on the Myosoft 1200 EMG unit was used, and wire and electrode movement were minimized.

3. PROBLEM. Poor electrode conduction.

SOLUTION. The skin was abraded with alcohol wipes to increase conductivity, and tape was placed over the electrode to help the electrode adhere to the skin.

4. PROBLEM. Excess crosstalk of muscles.

SOLUTION. Crosstalk was minimized by placing the electrodes where there would be minimal overlap of the internal and external obliques. Subjects were tested within a sub-maximal level of exertion.

5. PROBLEM. Muscle fatigue with greater than five repetitions.

SOLUTION. Subjects were instructed how to perform the test correctly and allowed a one-minute rest between trials.

6. PROBLEM. Asymmetry of muscle, that is the firing of obliques related to inaccurate technique or muscle imbalance.

SOLUTION. Subjects were instructed verbally and guided into precise trial position by the same examiner.

7. PROBLEM. Muscle activity increases with respiration or valsalva maneuvers.

SOLUTION. Subjects were instructed to count to five slowly while performing all trials.

8. PROBLEM. Subject attitude, motivation, and health on the day of testing.

SOLUTION. Subjects were questioned concerning their general health on the day of testing, addressed in a pleasant, non-threatening manner, and asked if they had any questions or comments before the testing began.

9. PROBLEM. Lack of communication and possible differences in test procedure.

SOLUTION. All subjects were given the same instructions and guided through the procedure in the same sequence. All examiners performed the same test role with each subject.

CHAPTER 4

ANALYSIS OF DATA

Descriptive Data

The study was comprised of 40 subjects who participated in subject testing and test-retest reliability of the "easy" positions. Eight additional subjects participated in the pilot study and the test-retest reliability study of the "hard" positions. Some subjects participated in more than one of the above studies. All of the subjects passed the inclusion criteria for abdominal strength, hamstring length, skin-fold thickness, and general health.

Subject testing involved all 40 subjects, of which, 24 women and 16 men ranged in age from 18 to 69. The mean age was 24.7, while the median age was 22.5. All subjects were students or faculty affiliated with GVSU. A majority of the students were members of a GVSU sports team.

Subject Testing Results

Software, titled SPSS 6.1 for Windows was used to determine if there was a normal distribution curve between the two muscles for both tests (see Figures 1 & 2). The mean difference between the HE ratios of the internal and external obliques were used to plot the distribution curve because the muscles were not independent variables. The distribution curves for both tests appeared normal (see Figures 1 & 2).

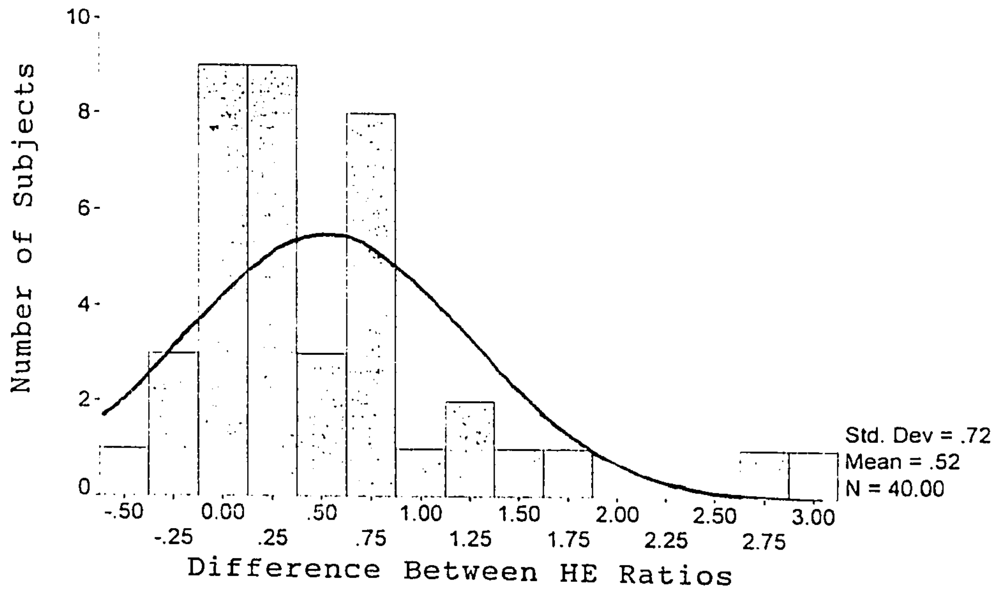

Figure 1. Internal oblique HE ratio minus external oblique HE ratio of the trunk-curl test for subject testing.

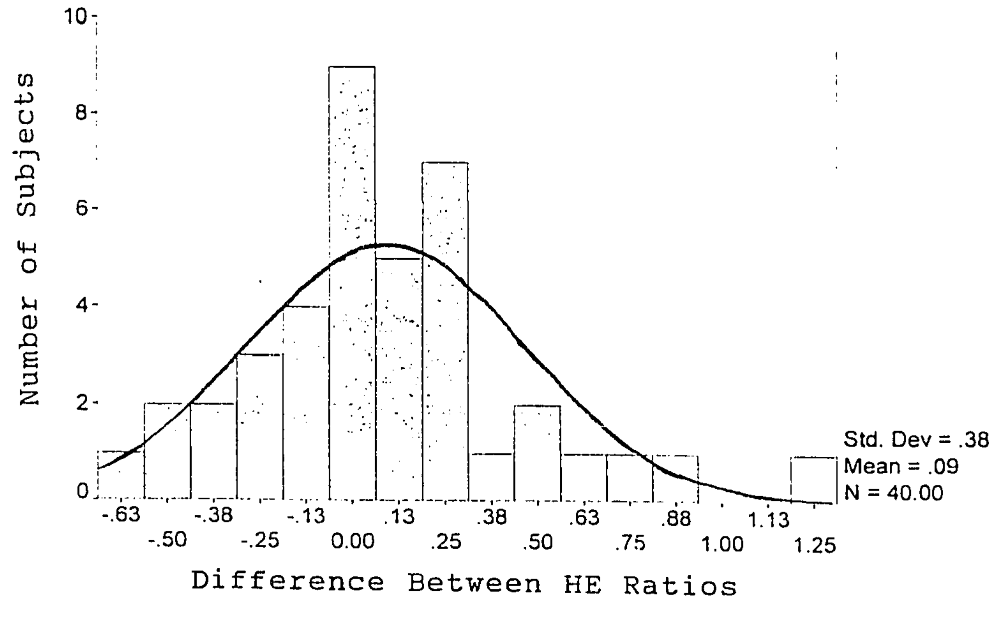

Figure 2. External oblique HE ratio minus internal oblique HE ratio of the leg-lowering test for subject testing.

Table 1 includes the mean and standard deviation pertaining to the internal and external obliques. The mean HE ratio for subject testing was derived by dividing the sum of the individual HE ratios by the number of subjects. Both muscles demonstrated mean ratios greater than one for each test. The external oblique's activity during the trunk-curl demonstrated the largest mean HE ratio overall (see Table 1). The lowest mean HE ratio overall was demonstrated by the external oblique activity during leg-lowering (see Table 1).

Table 1
Mean HE Ratio and Standard Deviation For Subject Testing

	Sample size	Mean HE Ratio	Standard deviation
Internal Oblique Trunk-Curl	40	1.174	0.431
External Oblique Trunk-Curl	40	1.692	0.723
Internal Oblique Leg-Lowering	40	1.253	0.424
External Oblique Leg-Lowering	40	1.162	0.341

A paired t-test was used to compare the difference in HE ratios between the internal and external obliques of each individual for each test. Significance of the data was determined by a comparison of the one-sided P-value obtained in the unidirectional paired t-test to the alpha level (alpha = 0.05). There was no significant difference in HE ratios between the muscles for the trunk-curl or leg-lowering tests (see Table 2).

Table 2

Subject Testing Results of t Tests Comparing External With Internal Oblique

	Number of Pairs	t-Statistic	Critical Value	One-Sided P-Value	Significance
Trunk-Curl	40	-4.54	2.02	0.999	No
Leg-Lowering	40	-1.53	2.02	0.933	No

Subgroup Results

The 40 subjects demonstrated HE ratios ranging from less than one to greater than one. Only the ratios greater than one met our initial assumption, that is, that the "hard" position would generate more muscle activity than the "easy" position. Of the total number of subjects, 63 percent demonstrated a HE ratio greater than one. The subjects that had HE ratios greater than one were called the "subgroup." Two subgroups were established, one for the trunk-curl test with 25 subjects and one for the leg-lowering test with 29 subjects.

Each subgroup was analyzed for normal distribution of the mean differences between the obliques for both tests. Approximate normal distributions were found for both tests between the two muscles (see Figures 3 & 4).

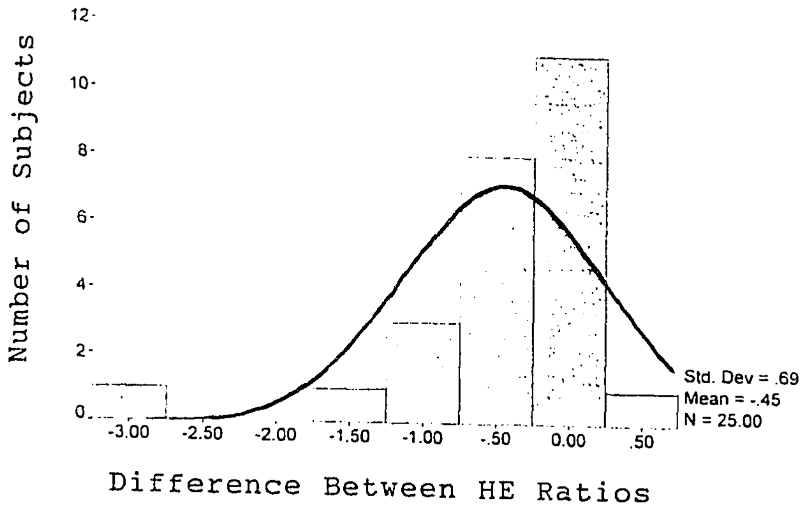

Figure 3. Internal oblique HE ratio minus external oblique HE ratio of the trunk-curl for subgroups.

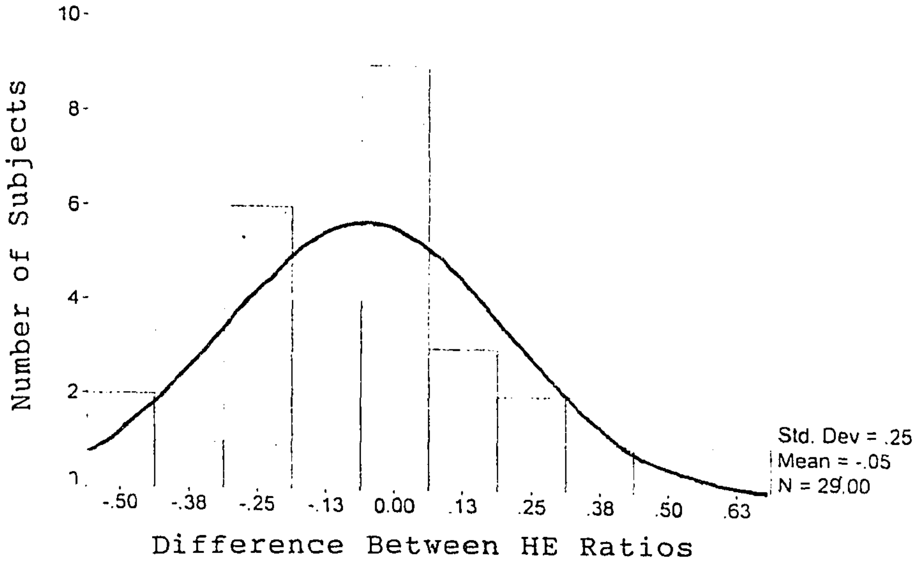

Figure 4. External oblique HE ratio minus internal oblique HE ratio of the leg-lowering test for subgroups.

Table 3 for the subgroup includes the mean HE ratio and the standard deviation for the obliques during the trunk-curl and leg-lowering tests (see Table 3). All tests show mean ratios greater than one. The largest mean HE ratio was demonstrated by the external oblique during the trunk-curl (see Table 3). The lowest mean HE ratio was demonstrated by the external oblique during the leg-lowering test (see Table 3).

Table 3

Mean HE Ratio and Standard Deviation For Subgroups

	Sample Size	Mean HE Ratio	Standard Deviation
Internal Oblique Trunk-Curl	25	1.396	0.368
External Oblique Trunk-Curl	25	1.845	0.731
Internal Oblique Leg-Lowering	29	1.369	0.257
External Oblique Leg-Lowering	29	1.315	214

The paired t-test results for the trunk-curl with 25 pairs and leg-lowering with 29 pairs show P-values above the set alpha level of 0.05. Therefore, no statistical significance was found (see Table 4).

Table 4

Subgroups Results of t-Tests Comparing External With Internal Oblique

	Number of Pairs	t-Statistic	Critical Value	One-Sided P-Value	Significance
Trunk-Curl	25	-3.233	2.064	0.998	No
Leg-Lowering	29	-1.153	2.048	0.871	No

Test-Retest Reliability

The EMG data from the 3 trials of the "easy" positions that all the 40 subjects performed during the study was used as a test-retest reliability study. Five subjects participated in the test-retest reliability of the "hard" position separate from the procedure of the testing. A reliability coefficient of 0.90 was considered appropriate for the study. The results of the test-retest reliability study for all 40 subjects showed a reliability coefficient of 0.95 for E-TC and 0.98 for E-LL. The reliability results for 5 subjects showed a coefficient of 0.83 for H-TC and 0.97 for H-LL (see Table 5).

Table 5

Test-Retest Reliability of the Test Positions

	Test-Retest Reliability Coefficient
Easy Trunk-Curl (E-TC)	0.95
Easy Leg-Lowering (E-LL)	0.98
Hard Trunk-Curl (H-TC)	0.83
Hard Leg-Lowering (H-LL)	0.97

CHAPTER 5

DISCUSSION AND IMPLICATIONS

Results Within Theoretical Framework

The study does not support the hypotheses that the internal oblique recruits more than the external oblique during the trunk-curl test or that the internal oblique recruits less than the external oblique during the leg-lowering test. The inability to detect differences in recruitment patterns is possibly due to limitations in the study, or perhaps, there really is no significant difference in muscle activity between the two tests. The study, however, had a high test-retest reliability regarding the test positions and is a study design worthy of future research.

The beauty of research often lies in surprises. The unexpected results required a reexamination of the basic assumption in the study design. The study assumed more muscle activity was required for the "hard" position than the "easy" position. The ratio of "hard" divided by "easy" was expected to be greater than one. Recognizing that the assumption did not hold for many of the subjects, further analysis was done with subjects meeting the assumptions. Two subgroups were analyzed, one for the trunk-curl and one for leg-lowering. The same paired t-test that was used for the subject testing was applied to the subgroups and these results also showed no significant difference between the muscles.

Review of Findings

The subject testing and subgroup results, for all the tests, using the unidirectional paired t-test reflect p-values above the set alpha level (0.05), consequently, the null hypothesis is not rejected.

When using the unidirectional paired t-test, a negative value of the t-statistic implies results are in the opposite direction (Portney & Watkins, 1993). The subject testing results for the trunk-curl shows a t-statistic of -4.54, which is below it's critical value of 2.02. The subgroups demonstrated a similar pattern for the trunk-curl with a t-statistic of -3.22, which is below it's critical value of 2.06. The alternative hypothesis is unidirectional but the results reflect both directions for the trunk-curl test. That is, for the trunk-curl, the external oblique showed more muscle activity than the internal oblique. These results suggest a two-tailed t-test would be more appropriate to determine statistically significant differences between the muscles.

The reproducibility of E-TC, E-LL, and H-LL test positions is considered high since all the test-retest reliability coefficients are greater than 0.95. A reliability coefficient greater than 0.90 is considered high enough to ensure valid interpretation of results (Portney & Watkins, 1993). All positions show acceptable test-retest reliability coefficients except the H-TC. The test-retest reliability coefficient of 0.83 for the H-TC is based on only 5 subjects. The low sample size for the test-retest reliability analysis of the H-TC is possibly the reason for the low coefficient. Nonetheless, the test-retest reliability results lend credibility to the testing technique.

Results Compared to Literature

The study is similar to past studies with respect to the variability of muscle activity during abdominal exercises, the difficulty in measuring the lateral fibers of the internal oblique, and the ability to generate an acceptable intraday, test-retest reliability for a manual muscle test position.

Since the statistics do not reject the null hypothesis, the possibility that there really is no significant difference in muscle activity between the two tests is plausible. The variability of recruitment is possibly a result of individual muscle preference or individual body types. The variability of muscle activity recruitment for the obliques and rectus abdominis during trunk-curl and leg-raising exercises was cited in the literature review. Walters and Partridge (1957) found the trunk-curl to be a good exercise for all abdominal muscles and Floyd and Silver (1950) found both the obliques and the rectus abdominis to be active with leg-raising. Kendall (1993) postulates that different body postures and the resulting different muscle lengths influence muscle strength tests. There is also evidence that the obliques may be more active with rotational trunk movements than symmetrical movements based on a study by Flint and Gudgel (1950).

The challenges with the electrode placement to measure the muscle activity of the lateral fibers of the internal oblique is similar to the observations found by the Marras and Mirka (1992) study. Their study concluded that there was a high risk of crosstalk with the electrodes on the lumbar triangle of petit (Marras & Mirka, 1992).

Lastly, the high test-retest reliability of the test positions substantiated the reliability data for normal muscle testing described by Iddings, Smith, and Spencer (1961).

Limitations of the Study

Limitations of the study are divided into two main areas--design and random errors. Design errors are consistent throughout the study and effect the subjects equally as a group. In contrast, random errors influence the subjects inconsistently.

The study has design limitations including: (1) measuring only two of the four abdominal muscles; (2) not using an ideal electrode placement of the internal oblique; (3) too narrow of a spread between the "easy" and "hard" positions; (4) incorrect subject positions for H-TC; and (5) statistical limitations.

The four abdominal muscles are the internal oblique, external oblique, transversus abdominis, and rectus abdominis. Since only the internal and external obliques were measured, the conclusions are limited to these muscles. Therefore, the subjects' level of recruitment of the rectus abdominis and transversus abdominis during the upper and lower abdominal positions is unknown.

The second design error concerns the electrode placement for the internal oblique. As a result of the pilot study, the lateral internal oblique electrode placement was moved to an anterior location. Any conclusions from the data are limited to assessing only the anterior transverse fibers of the internal oblique. The anterior internal oblique fibers are not the fibers involved with trunk-curl and may not assess Kendall's theories directly.

The third design error is the narrow spread between the "hard" and "easy" positions for each test. Many subjects have a HE ratio very close to one, suggesting little difference in muscle recruitment between the two test positions. The study failed to generate all positive values representing the muscle activity during a test, possibly due to the narrow spread between the positions.

The fourth design error relates to incorrect subject positioning for H-TC. The study was designed so the subject's position remained in the trunk-curl phase. The procedure was designed to avoid the hip flexion phase to limit the amount of co-contraction of the hip flexors. Regrettably the design limited the subjects from reaching a strong trunk-curl. Kendall asserts that the greatest demand on the internal oblique occurs as the hip flexion phase begins (F. P. Kendall, personal communication, March 7, 1996). Therefore, a design error is possible based on measuring the internal oblique when its maximum muscle activity is not occurring (F. P. Kendall, personal communication, March 7, 1996).

Lastly, the statistical limitations are due to the small sample size, and the sample characteristics limited to primarily athletes enrolled at GVSU. A sample size of 40 is small for generalizations to a larger population. A larger sample would be more representative of population characteristics (Portney & Watkins, 1993).

Besides design errors that affect all subjects, the study is limited by random errors which do not necessarily affect all subjects in the same way. Possible sources for random errors are: (1) the subject's muscle fatigue, (2) the subject's lack of coordination to hold the test positions, (3) the subject's excessive use of muscle activity during the test, (4) the examiner positioning the subject inconsistently, (5) physiological variations between subjects, and (6) human and technical errors.

If the obliques are fatigued, it is possible that some subjects are holding the test position using other muscles. Since the study did not measure all the abdominals, it is hard to discern which muscles were being used to hold the test position. The possibility exists that the EMG readings of the obliques were low due to fatigue. Kendall supports the theory that if the obliques fatigue during the abdominal tests, the rectus abdominis is able to compensate and may be the primary trunk flexing muscle (F. P. Kendall, personal communication, March 7, 1996).

The second random error is that some subjects have less motor control than other subjects for the same positions. During the E-TC, but not during the H-TC, there was noticeable shaking of the trunk and shoulders for many subjects. The shaking was possibly due to lack of motor control. Theoretically, a subject with less motor control for a certain position uses more muscle activity to hold an unfamiliar position than after becoming proficient for the same position. The "hard" positions are similar to the strengthening program many of the subjects participate in at GVSU, whereas, the "easy" positions are not a known strengthening position used by the subjects. The lack of motor control is possibly an explanation for the narrow spread between the "easy" and "hard" EMG output.

The third random error is due to unnecessary and excessive muscle activity while holding the test position. Some subjects exert excessive muscle activity while holding their breath during the trial or use more muscle activity than necessary to hold the test position.

The inability to consistently direct each subject into the same test position is the forth random error. Even though the testing is standardized and consistent between subjects, dramatic EMG amplitude changes are observable when the subject makes very small positional changes.

The fifth random error is the physiological variability between subjects that leads to a decrease in the EMG signal. There was low-level EMG readings in the single digits for several subjects. Yet, most subjects generated raw data in the hundreds of μV for a three-second interval. Possible physiological driven errors are high skin-fold impedance, or the motor units with adequate signals were not within the EMG pick-up zone.

Lastly, opportunities exist for human and technical errors during the study. Human and technical errors include inconsistent electrode attachment, movement of electrode cables, inaccurate synchronization of EMG recording with subject positioning, noise generated within the EMG, and data entry errors.

Strengths of the Study

The study is the first attempt to analyze Kendall's abdominal strength tests. Though there are limitations, the design has strong characteristics that are valid to use for future studies. The procedure is thoroughly documented in the appendix and has strengths worth mentioning. First, each examiner has assigned duties with consistent verbal and manual instructions being used with the subjects. Secondly, all controllable variables are addressed, that is, consistent electrode placement for all subjects using anatomical landmarks. Lastly, the procedure of guiding a subject into the test position is reproducible, reflected by the high test-retest reliability.

Conclusions/Recommendations

The study is not able to make any strong conclusions regarding Kendall's abdominal strength tests due to limitations found in the design. Two critical limitations in the design were: (1) the necessity to place the internal oblique electrode on the anterior fibers, and (2) the basic assumption, that is, the "hard" position requires more muscle activity than the "easy," was not met for all subjects.

The results of the HE ratio demonstrate the need for further research regarding Kendall's abdominal strength grades, that is, the muscle activity difference between the "normal" grade versus the "fair" grade. With more information regarding the muscle activity of Kendall's strength grades, a study analyzing the individual muscle's activity is more feasible.

For future investigations of Kendall's abdominal strength tests it is recommended to use fine-wire electrodes to accurately record the lateral fibers of the internal oblique. Although surface electrodes are more beneficial than fine-wire in analyzing large muscle groups, the internal oblique's lateral fibers are deep and difficult to reach using surface

EMG. In addition, the rectus abdominis and perhaps the transversus abdominis are also key muscles that should be monitored to quantify their respective muscle activity during Kendall's abdominal strength test.

Another alternative method for future investigation is the use of a dynamic EMG analysis. A dynamic test design allows the inferences drawn from the data more applicable to Kendall's abdominal strength tests.

If isometric positions are used in further research, we recommend the following changes in our design. Rather than a spread of less than one muscle grade for each test, it is recommended to use a spread wider than the "easy" and "hard" positions. The wider spread would allow for a more distinct difference in muscle activity. Lastly, to address the influence of motor control, it is recommended that all subjects have an opportunity to become proficient with the positions.

Application of this study to a clinic or educational setting is possible even though the results are inconclusive. The limitations found in the study are applicable when Kendall's abdominal tests are used in a clinic. Correct alignment and technique are essential for reliable testing. A patient's ability to achieve a position is influenced by individual variables, such as: past experience with the test position, that is, motor control; posture and strength of individual abdominal muscles; and the ability to follow instructions regarding the test position. The patient's test results are only applicable to the patient's retest results later, and are not comparable to others. The applications for the clinic also apply to the educational setting. This study is intended as a stepping stone for further questions and investigations regarding Kendall's manual muscle test.

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APPENDIX A.

Kendall's Manual Muscle Test Positions and Techniques

Kendall's Technique for Testing the Upper Abdominals

There are two phases for the upper abdominal strength test: spine flexion (trunk-curl) phase and hip flexion (sit-up) phase (Kendall et al., 1993). To have a "fair+" grade or better, the subject must complete both phases while maintaining a flexed spine. The subject begins the test in supine position with the legs straight, and the heels resting on the table.

The subject completes the trunk-curl phase by contracting the abdominal muscles, flexing the upper back, and flattening (flexing) the low-back against the table. Support of the feet must not occur until the trunk flexion phase is complete and the hip flexion phase begins. By not supporting the feet during the trunk flexion phase the abdominals are recruited rather than the hip flexors to maintain the flexed spine (Kendall et al., 1993).

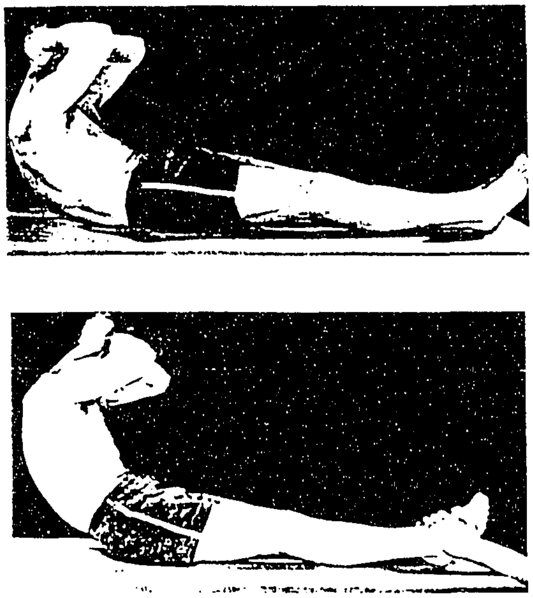
During the hip flexion phase, the flexed trunk is raised up from the table by the hip flexors pulling anteriorly on the pelvis. If the abdominals are strong, the spine flexion will be maintained as hip flexion is initiated. The hip flexion phase provides the greatest resistance against the upper abdominals because the abdominals must maintain a posterior tilt (maximum spine flexion) against the anterior force on the pelvis as hip flexion begins.

Many subjects need to have the feet held down during the hip flexion phase.

Stabilizing the feet must not occur until trunk flexion is complete and the hip flexion phase begins. Precision in testing requires that the abdominals flex the spine before hip flexion takes place (Kendall et al., 1993).

To vary the resistance to the abdominals the arms are extended straight forward, or folded across the chest, or placed behind the head with the hands clasped (Kendall et al., 1993). The muscle strength grade is determined by the position of the arms and completion of the hip flexion phase while maintaining maximum spine flexion (for "fair +," "good," and "normal" grades). In a "fair" grade (arms are extended straight forward) the subject is able to flex the trunk to subject's maximum but is unable to keep the trunk flexed when hip flexion is initiated.

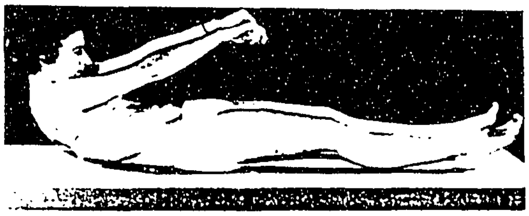
Kendall's Grading of the Upper Abdominal Muscles



Normal (10) grade:* With hands clasped behind the head, the subject is able to flex the vertebral column (top figure), and *keep it flexed while entering the hip-flexion phase and coming to a sitting position* (bottom figure). Feet may be held down during the hip-flexion phase, if necessary, but close observation is required to be sure that the subject maintains the flexion of the trunk.

Because many people are able to do the curled-trunk sit-up with hands clasped behind the head, it is usually permissible to have a subject place the hands in this position, initially, and attempt to perform the test. However, if there is concern about the difficulty of the test, start with the arms reaching forward, progress to placing arms folded across the chest, and then to hands behind the head.

Good (8) grade. With arms folded across the chest, the subject is able to flex the vertebral columm and *keep it flexed while entering the hip-flexion phase and coming to a sitting position.*



Fair+ (6) grade. With arms extended forward, the subject is able to flex the vertebral column and *keep it flexed while entering the hip-flexion phase and coming to a sitting position.*

Fair (5) grade. With arms extended forward, the subject is able to flex the vertebral column, but is unable to maintain the flexion when attempting to enter the hip-flexion phase.

See p. 176 for tests and grades in cases of marked weakness of anterior trunk muscles.

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*See numerical equivalents for word symbols used in grading, p. 188; and *Key to Muscle Grading*, p. 189.

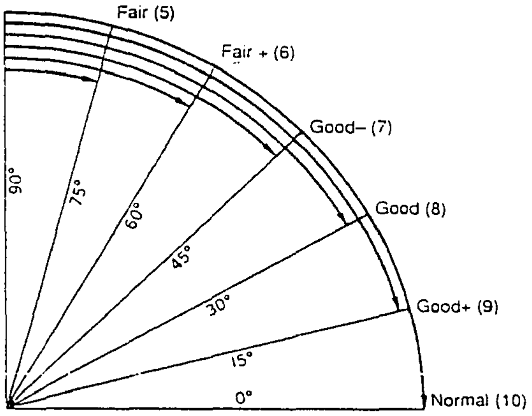
Used with permission. Kendall, F., McCreary, E., & Provance, P. Muscles: Testing and Function 4th ed., Williams & Wilkins, 1993.

Kendall's Technique for Testing the Lower Abdominals

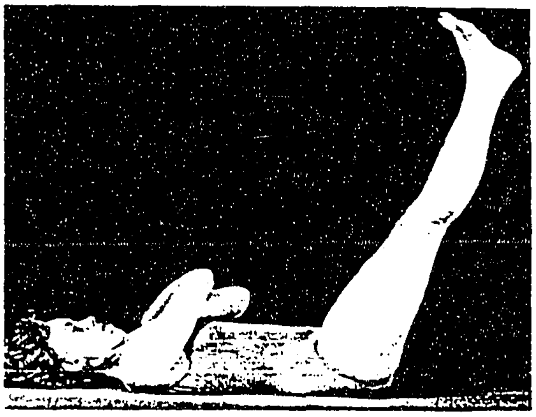
The lower abdominal strength test begins with the subject supine on a table with arms folded across the chest. The subject's knees are extended and the ankles are in a relaxed position. The subject is not supported in any way. If hamstring length is normal, the legs are raised by the examiner to an angle of about 80 degrees of hip flexion. The subject is asked to maintain the low-back flat against the table while slowly lowering the legs. As the legs are lowered, the lever arm increases, thereby increasing the resistance against the lower abdominal muscles that are working to hold the low back and pelvis flat on the table (Kendall et al., 1993).

The angle created between the legs and the table is used as the measurement to determine a muscle strength grade. The subject has gone beyond the grade of strength when the pelvis begins to tilt anteriorly and the low-back is no longer flat on the table. Lowering to an angle of 75 degrees is considered a "fair" muscle grade. An angle of 60 degrees is a "fair+," an angle of 45 degrees is a "good-," and an angle of 30 degrees is considered a "good" muscle grade (Kendall et al., 1993).

Kendall's Grading of the Lower Abdominal Muscles



See numerical equivalents for word symbols used in grading, p. 188; and *Key to Muscle Grading*, p. 189.



Fair+ (6) Grade: With arms folded across chest, the subject is able to keep the low back flat on the table while lowering the legs to an angle of 60° with the table.

Good (8) Grade: With arms folded across the chest, the subject is able to keep the low back flat while lowering the legs to an angle of 30° with the table. (In this illustration, the legs are at a 20° angle.

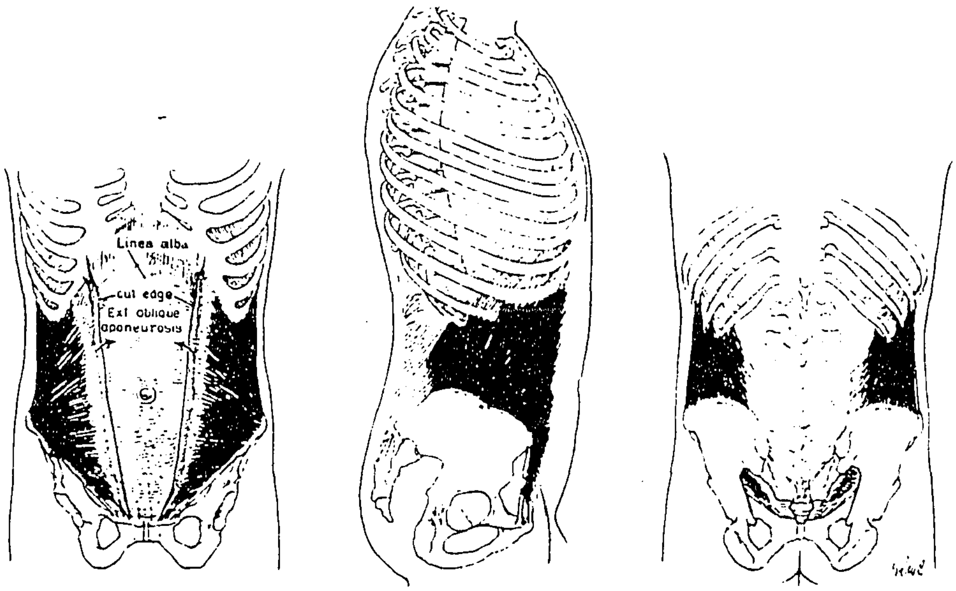
Normal (10) Grade: With arms folded across the chest, the subject is able to keep the low back flat on the table while lowering the legs to table level. (The legs are elevated a few degrees for the photograph.)

Used with permission. Kendall, F., McCreary, E., & Provance, P. Muscles: Testing and Function 4th ed., Williams & Wilkins, 1993.

APPENDIX B.

Abdominal Oblique Anatomy

Internal Oblique Anatomy



INTERNAL OBLIQUE, LOWER ANTERIOR FIBERS

Origin: Lateral two thirds of inguinal ligament, and short attachment on iliac crest near anterior superior spine.

Insertion: With Transversus abdominis into crest of pubis, medial part of pectineal line, and into linea alba by means of an aponeurosis.

Direction of Fibers: Fibers extend transversely across lower abdomen.

Action: The lower anterior fibers compress and support the lower abdominal viscera in conjunction with the Transversus abdominis.

INTERNAL OBLIQUE, UPPER ANTERIOR FIBERS

Origin: Anterior one third of intermediate line of iliac crest.

Insertion: Linea alba by means of aponeurosis.

Direction of Fibers: Fibers extend obliquely medialward and upward.

Action: Acting *bilaterally*, the upper anterior fibers flex the vertebral column, approximating the thorax and pelvis anteriorly, support and compress the abdominal viscera, depress the thorax, and assist in respiration. Acting *unilaterally*, in conjunction with the anterior fibers of the External oblique on the opposite side, the upper anterior fibers of the Internal oblique rotate the vertebral column, bringing the thorax backward (when the pelvis is fixed), or the pelvis forward (when the thorax is fixed). For example, the right Internal oblique rotates the thorax clockwise, and the left Internal oblique rotates the thorax counterclockwise on a fixed pelvis.

INTERNAL OBLIQUE, LATERAL FIBERS

Origin: Middle one third of intermediate line of iliac crest, and thoracolumbar fascia.

Insertion: Inferior borders of 10th, 11th, and 12th ribs and linea alba by means of aponeurosis.

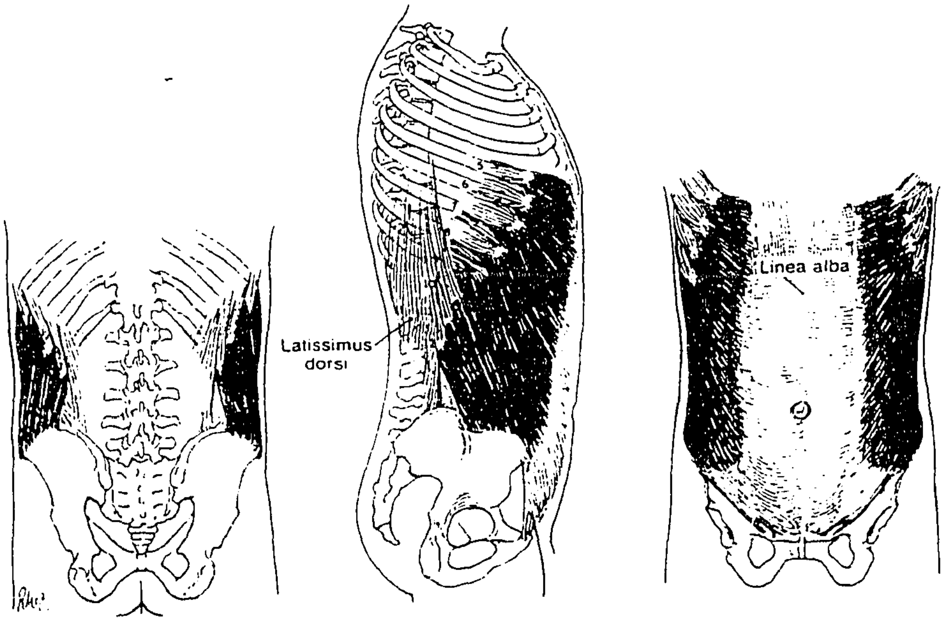
Direction of Fibers: Fibers extend obliquely upward and medialward, more upward than the anterior fibers.

Action: Acting *bilaterally*, the lateral fibers flex the vertebral column, approximating the thorax and pelvis anteriorly, and depress the thorax. Acting *unilaterally* with the lateral fibers of the External oblique on the same side, these fibers of the Internal oblique laterally flex the vertebral column, approximating the thorax and pelvis. These fibers also act with the External oblique on the opposite side to rotate the vertebral column.

Nerves to anterior and lateral fibers: T7–11, T12, Iliohypogastric and ilioinguinal, ventral rami.

Used with permission. Kendall, F., McCreary, E., & Provance, P. Muscles: Testing and Function 4th ed., Williams & Wilkins, 1993.

External Oblique Anatomy



EXTERNAL OBLIQUE, ANTERIOR FIBERS

Origin: External surfaces of ribs five through eight interdigitating with Serratus anterior.

Insertion: Into a broad, flat aponeurosis, terminating in the linea alba, a tendinous raphe which extends from the xiphoid.

Direction of Fibers: The fibers extend obliquely downward and medialward with the uppermost fibers more medialward.

Action: Acting *bilaterally*, the anterior fibers flex the vertebral column approximating the thorax and pelvis anteriorly, support and compress the abdominal viscera, depress the thorax, and assist in respiration. Acting *unilaterally* with the anterior fibers of the Internal oblique on the opposite side, the anterior fibers of the External oblique rotate the vertebral column, bringing the thorax forward (when the pelvis is fixed), or the pelvis backward (when the thorax is fixed). For example, with the pelvis fixed, the right External oblique rotates the thorax counterclockwise, and the left External oblique rotates the thorax clockwise.

Nerves to anterior and lateral fibers: T5, 6, T7–12.

EXTERNAL OBLIQUE, LATERAL FIBERS

Origin: External surface of ninth rib, interdigitating with Serratus anterior; and external surfaces of 10th, 11th and 12th ribs, interdigitating with Latissimus dorsi.

Insertion: As the inguinal ligament, into anterior superior spine and pubic tubercle, and into the external lip of anterior one half of iliac crest.

Direction of Fibers: Fibers extend obliquely downward and medialward, more downward than the anterior fibers.

Action: Acting *bilaterally*, the lateral fibers of the External oblique flex the vertebral column, with major influence on the lumbar spine, tilting the pelvis posteriorly. (See also action in relation to posture, p. 161.) Acting *unilaterally* with the lateral fibers of the Internal oblique on the same side, these fibers of the External oblique laterally flex the vertebral column, approximating the thorax and iliac crest. These External oblique fibers also act with the Internal oblique on the opposite side to rotate the vertebral column. The External oblique, in its action on the thorax, is comparable to the Sternocleidomastoid in its action on the head.

APPENDIX C.

Recruitment Forms

***GOLDEN OPPORTUNITY!!!!!!!! ***

Participate in a ground-breaking study!!

FOR MORE INFORMATION CALL 616 847-8624 OR SIGN BELOW !!

Seeking healthy adults to participate in a thesis study to evaluate the strength of abdominal muscles in two test positions.

We only need 30 minutes of your time at the physical therapy lab on campus (10 minutes for prescreen test and 20 minutes for data collection).

Participants **must be able to perform a complete sit-up and partial leg-lowering exercise**. General abdominal strength will be tested in the prescreen along with a skin-fold measurement to test for percent body fat (participants should be no more than 20 lbs over their age-predicted body weight). Participants must be adults, in general good health, and without any back injury in the past 3 years. Participation will be confidential.

YOU GET: *Your personal abdominal strength grade.

*Both abdominal strength exercises will be taught.

***Free snacks and beverages** will be available (to eat and drink in a building that allows it!).

*A copy of the final study will be available upon request (the thesis will also be presented to the public in April).

SIGN UP!!!! You will be contacted to schedule a time for the prescreen and data collection

OR CALL!!! 616 847-8624, leave your name and number and we'll call you back.

Name: ______________________ **Phone #**

Letter to Coaches

January 10, 1996

Ms. Rebecca Currier, SPT
15894 Vinecrest Ave.
Spring Lake, MI 49456
(616)847-8624

Grand Valley State University Coaches
Allendale, MI

Dear Coaches:

My thesis partner (Ms. Margie Johnson) and I are designing a study to test two abdominal muscle test positions.

Our research question is: Does Florence Kendall's manual muscle test positions for the upper and lower abdominals differentiate the recruitment of muscle fiber firing as measured using surface electromyography on the internal and external obliques?

We would greatly appreciate the participation of your team members as subjects in this study. As a participant they will be instructed in abdominal strengthening and will have the results of their individual abdominal strength. Testing will take place in the physical therapy lab on campus, and will take about 30 minutes per person. The study results and full report will also be available for each participant.

Enclosed is a sign-up sheet along with the requirements to be involved in this study.

I will be contacting you later this week for questions and scheduling interested team members. Thank you for reviewing this material and bringing it to the attention of your team.

Sincerely,

Rebecca A. Currier, SPT

APPENDIX D.

Prescreen Forms

PRESCREEN TEST & SEQUENCE FOR DATA COLLECTION

Name ________________________ Address ___________________________________

Phone # (optional) __________________ Age _____ Sex ____ Pilot Subject Y N

Reliability Subject Y N

Which GVSU sport team, if any, are you on? ________________

In the last 3 years have you had any back injuries? Y N

Skin-fold (5-18 mm) ____ mm; Spine flexion adequate Y N ; SLR ($\geq$70 deg)L/R____

Subject stretch hamstrings? Y N

MMT: Abd. Curl (arms folded) "good" grade for 10 seconds Y N ; MMT Grade _______

Leg-Lowering (45 deg) "good -" grade for 10 seconds Y N ; MMT Grade______

Subject understands where electrode placement is? Y N Need for shaving area? Y N

Subject understands the 4 test positions and that there are 8 trials? Y N

Would you like to be notified of the thesis presentation open to the public? Y N

Would you like a copy of the thesis abstract? Y N Data collection scheduled for ______

Filled out postcard and gave to subject Y N

I'd like you to know that you may terminate your participation in this study at any time by notifying us by phone or by mailing us your appointment postcard. You are not required to give your reasons. Do you have any questions?

APPOINTMENT AND CANCELLATION POSTCARD

ELECTROMYOGRAPHIC COMPARISON USING KENDALL'S MANUAL MUSCLE TEST POSITIONS FOR UPPER AND LOWER ABDOMINALS

Your data collection is scheduled for: Date ________Time ________.

Place: Grand Valley State Univ., Henry Hall, Room 303

Clothing: Loose fitting clothing, athletic shorts, or bikini bottoms

Note: Only the examiners (Margie Johnson and Rebecca Currier) and subject (yourself) will be in the testing room. Your participation is confidential.

If at any time you would like to terminate your participation in this study, you may phone us at 616-847-8624 or 616-866-3624, or mail us this postcard.

PRESCREEN MANUAL MUSCLE TEST RESULTS AND ABDOMINAL EXERCISES

* Manual Muscle Test for Abdominal Curl Sit-Up:

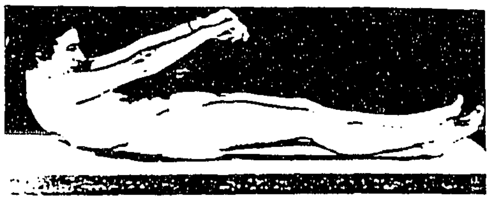
Normal, Good, Fair+, and Fair.

* Manual Muscle Test for supine Bilateral Leg-Lowering:

Normal, Good+, Good, Good-, Fair+, and Fair.

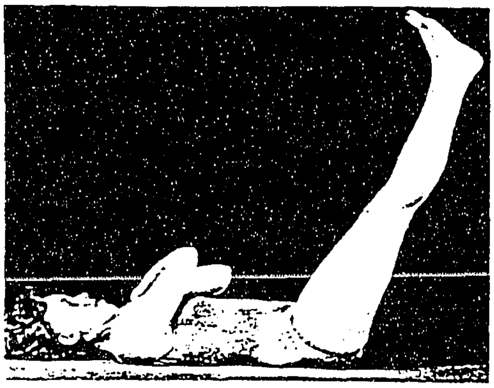
Grading Upper Abdominal Muscles

Good (8) grade. With arms folded across the chest, the subject is able to flex the vertebral column and *keep it flexed while entering the hip-flexion phase and coming to a sitting position.*

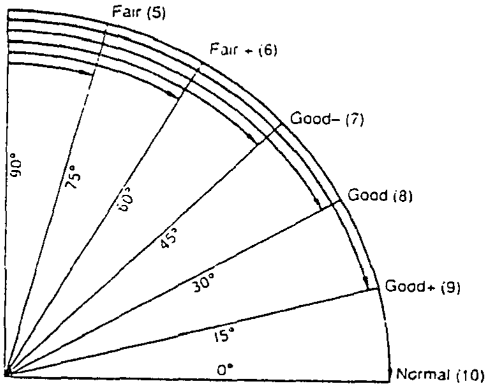


Fair (5) grade. With arms extended forward, the subject is able to flex the vertebral column, but is unable to maintain the flexion when attempting to enter the hip-flexion phase.

Grading Lower Abdominal Muscles



Fair + (6) Grade: With arms folded across chest, the subject is able to keep the low back flat on the table while lowering the legs to an angle of 60° with the table.



See numerical equivalents for word symbols used in grading, p. 188; and *Key to Muscle Grading*, p. 189.

Used with permission. Kendall, F., McCreary,E., & Provance, P. Muscles: Testing and Function 4th ed., Williams & Wilkins, 1993.

APPENDIX E.

Consent Form

CONSENT FORM

I understand that this is a research study analyzing two muscle test positions as proposed by Kendall for differentiating between the strength of the upper and lower abdominal. The knowledge gained is expected to help physical therapists and physicians to perform abdominal strength tests and is expected to help healthcare professionals in a manner with a greater understanding of the specific muscles that are being challenged.

I also understand that:

> "Participation in this study will involve a 30-minute testing session held during a two-week period January 25 to February 7, 1996."
>
> "That I have been selected for participation because I fit the requirements for accurate measurement of muscle contraction (skin-fold thickness 5 to 18 millimeters, strength grade "good" or greater for the abdominal curl sit-up, strength grade "good-" or greater for the supine bilateral leg-lowering, and within normal range of motion for the spine and hamstrings)."
>
> "It is not anticipated that this study will lead to physical or emotional risk to myself. There may be slight skin irritation from the alcohol preparation, adhesive electrodes, or slight muscle soreness from

exertion."

"The information I provide will be kept strictly confidential and the data will be coded so that identification of individual participants will not be possible."

"An abstract will be made available to me upon completion of the thesis."

I acknowledge that:

"I have been given an opportunity to ask questions regarding this research study, and that these questions have been answered to my satisfaction."

"In giving my consent, I understand that my participation in this study is voluntary and that I may withdraw at any time using the postcard provided by Rebecca Currier, and Margie Johnson, without any penalty pertaining to the study."

"I hereby authorize the investigator to release the information obtained in this study to scientific literature. I understand that I will not be identified by name."

"I have been given Rebecca Currier and Margie Johnson's phone numbers so that I may contact either person, at any time, if I have questions."

"I acknowledge that I have read and understand the above information, and that I agree to participate in this study."

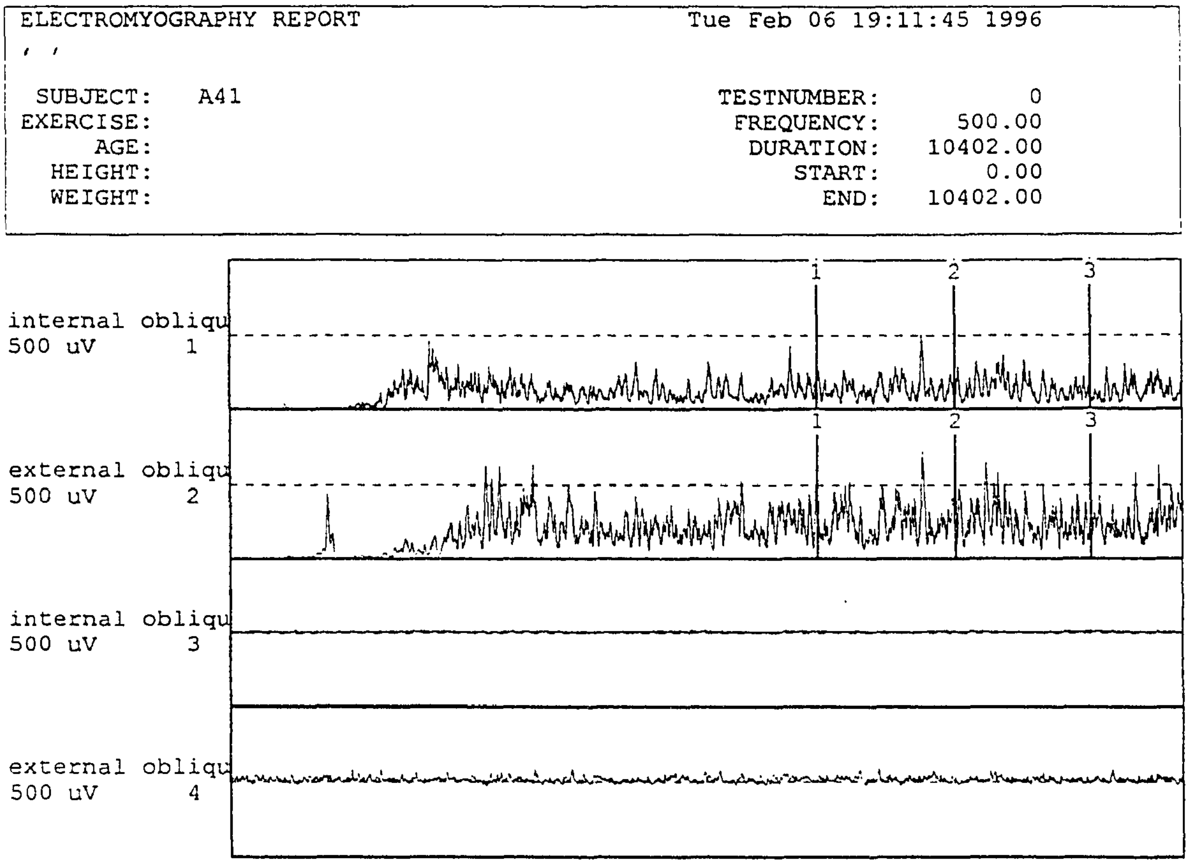
Witness	Participant's Signature
Date	Date

APPENDIX F.

Individual EMG Data Sheet

Subjects Raw Data File

Example of Subject #41



```
ELECTROMYOGRAPHY REPORT                      Tue Feb 06 19:11:45 1996
' '

 SUBJECT:   A41                                TESTNUMBER:         0
EXERCISE:                                       FREQUENCY:    500.00
     AGE:                                        DURATION:  10402.00
  HEIGHT:                                           START:      0.00
  WEIGHT:                                             END:  10402.00
```

Multiple Marker General Analysis Report

```
MULTIPLE MARKER GENERAL ANALYSIS                      Tue Feb 06 19:11:45 1996

 , ,

 SUBJECT:  A41, ,                                       TESTNUMBER:          0
EXERCISE:                                                FREQUENCY:     500.00
     AGE:                                                 DURATION:   10402.00
  HEIGHT:                                                    START:       0.00
  WEIGHT:                                                      END:   10402.00


 Channel   1         internal oblique
 Mark       Time     Value            Area      Total Area              Slope
    1     6402.0    109 uV           313.9           313.9             17.026
    2     7902.0     36 uV           104.5           418.4            -48.667
    3     9402.0     53 uV           104.1           522.5             11.333

 Channel   2         external oblique
 Mark       Time     Value            Area      Total Area              Slope
    1     6402.0    102 uV           498.3           498.3             15.933
    2     7902.0     80 uV           186.4           684.7            -14.667
    3     9402.0     68 uV           183.6           868.4             -8.000
```

APPENDIX G.

Data Collection Spread-Sheets

Pilot Study Spread-Sheet

	Fair Curl	Fair Curl	Fair Curl	Fair Curl	Fair Curl	Fair Curl	Good Curl	Good Curl	Fair Le
ID	Internal (A)	External (A)	Internal (B)	External (B)	Internal (C)	External (C)	Internal (D)	External (D)	Interna
A1	3.3	87.9	2.8	171.1	2.7	112.4	7.3	190.4	
A2	301.5	364.7	328.5	459.7	381.2	338.7	362.0	626.0	
A3	89.6	156.3	120.8	253.1	133.5	133.4	138.1	236.5	
A4	205.3	112.6	218.2	126.0	183.6	163.8	199.0	253.2	
A5	64.6	290.7	63.3	245.7	87.3	248.2	91.0	314.8	

r Leg	Fair Leg	Fair Leg	Fair Leg	Fair Leg	Fair Leg	Good Leg	Good Leg
rnal (E)	External (E)	Internal (F)	External (F)	Internal (G)	External (G)	Internal (H)	External (H)
1.8	95.0	1.8	89.2	6.9	87.2	1.9	92.0
33.5	211.9	93.5	220.6	92.7	234.4	81.0	155.8
77.1	138.4	66.7	119.9	73.7	138.5	120.3	121.0
86.4	78.3	90.9	81.2	110.5	78.7	134.5	79.7
93.2	97.5	94.1	102.5	80.1	102.9	8.7	37.9

Subject Testing and Reliability Study Spread-Sheet

	Fair Curl	Fair Curl	Fair Curl	Fair Curl	Fair Curl	Fair Curl	Good Curl	Good Curl	Fair Leg	Fair Leg	Fair Leg	Fair Leg	Fa
ID	Internal (A)	External (A)	Internal (B)	External (B)	Internal (C)	External (C)	Internal (D)	External (D)	Internal (E)	External (E)	Internal (F)	External (F)	Int
A1	3.3	87.9	2.8	171.1	2.7	112.4	7.3	190.4	1.8	95.0	1.8	89.2	
A2	301.5	364.7	328.5	459.7	381.2	338.7	362.0	626.0	33.5	211.9	93.5	220.6	
A3	89.6	156.3	120.8	253.1	133.5	133.4	138.1	236.5	77.1	138.4	66.7	119.9	
A4	205.3	112.6	218.2	126.0	183.6	163.8	199.0	253.2	86.4	78.3	90.9	81.2	
A5	64.6	290.7	63.3	245.7	87.3	248.2	91.0	314.8	93.2	97.5	94.1	102.5	
A6	282.0	507.3	299.3	357.8	300.9	468.1	339.6	806.8	246.8	241.3	288.5	269.9	
A7	248.1	282.9	252.1	394.8	294.0	412.9	240.0	589.6	178.8	218.0	155.7	182.0	
A8	213.4	26.7	212.4	27.3	209.3	37.5	209.8	52.0	113.4	21.4	140.6	37.4	
A9	335.4	66.8	277.8	63.3	303.6	64.8	291.1	108.1	64.8	67.1	120.1	67.2	
A10	246.2	575.0	252.4	405.7	254.2	577.4	238.6	528.5	78.6	135.2	67.6	133.7	
A11	9.4	23.5	6.9	25.1	0.3	0.1	10.3	45.4	5.6	42.5	4.4	22.1	
A12	358.1	104.1	457.2	85.7	405.0	93.2	414.7	83.5	125.3	69.6	119.0	70.0	
A13	202.1	132.1	253.7	126.4	68.7	99.5	85.1	103.3	47.7	82.5	137.1	94.5	
A14	27.4	153.0	21.2	147.9	13.5	259.8	7.5	285.8	8.0	217.4	2.6	268.3	
A15	226.1	324.1	189.2	289.8	208.4	197.3	201.7	172.7	72.4	253.5	75.8	233.9	
A16	369.6	87.8	385.2	65.3	447.7	86.8	538.1	135.7	223.0	122.4	156.7	132.9	
A17	320.6	153.6	303.7	146.9	290.8	142.3	344.1	158.4	216.1	150.9	123.4	84.9	
A18	247.6	268.4	263.2	184.2	334.2	275.0	165.5	565.5	160.8	221.3	104.7	180.9	
A19	362.8	58.4	298.7	50.9	291.0	51.8	383.7	79.3	77.2	73.2	76.6	76.8	
A20	151.8	151.8	125.4	137.8	136.2	175.1	128.4	177.4	164.6	233.8	197.7	293.6	
A21	120.9	128.6	181.5	86.2	127.9	26.1	190.8	110.0	166.0	256.6	156.2	207.7	
A22	114.3	93.4	98.7	98.9	112.1	104.4	131.2	100.5	66.1	195.1	71.4	170.1	
A23	132.1	35.6	106.6	43.6	129.5	48.6	126.0	80.3	196.3	113.1	228.8	124.7	
A24	159.3	44.7	150.4	109.5	203.6	226.5	211.5	165.6	97.6	130.6	99.2	134.2	
A25	151.7	157.7	373.6	142.4	230.6	87.6	299.8	157.3	121.8	115.8	96.7	119.3	
A26	708.7	71.9	634.2	86.0	675.4	69.1	666.6	111.1	323.6	66.0	301.4	39.8	
A27	100.7	61.2	236.7	197.1	149.8	84.2	233.7	167.9	156.5	115.5	94.3	71.4	
A28	345.9	92.6	297.9	74.6	399.8	88.9	304.5	123.0	333.5	200.4	294.3	206.7	
A29	148.9	34.9	42.9	22.5	51.2	20.8	87.4	34.3	65.9	17.5	62.3	39.1	
A30	286.5	112.9	197.5	129.6	377.5	159.0	389.6	197.5	231.4	155.1	261.6	142.8	
A31	108.2	45.7	150.0	54.3	135.1	65.4	156.6	84.3	100.6	58.0	87.2	60.2	
A32	93.9	10.5	99.8	18.2	87.3	9.6	144.0	37.7	130.9	136.2	141.8	102.7	
A33	260.5	42.6	257.9	42.7	246.7	50.3	166.4	44.1	43.7	80.5	59.1	81.2	
A34	140.6	34.7	121.3	20.5	150.7	71.7	280.9	138.6	321.5	239.0	343.9	214.0	
A35	179.4	21.9	388.0	41.6	210.9	23.2	508.6	77.5	243.2	142.1	308.7	130.4	
A36	100.9	35.5	99.3	63.4	171.0	123.8	125.8	293.4	157.6	337.6	129.0	274.4	
A37	205.5	84.3	180.8	56.9	104.8	26.8	232.5	92.7	85.8	92.5	99.5	109.1	
A38	305.0	24.5	200.6	19.9	206.9	24.2	217.3	24.7	122.4	74.0	133.6	89.1	
A39	50.0	13.9	84.7	36.6	45.8	24.8	28.0	80.6	86.6	210.7	96.4	217.5	
A40	103.6	18.2	72.7	16.6	106.2	29.3	114.6	39.8	105.6	84.7	101.3	91.0	
A41	96.3	188.4	147.2	284.9	69.8	73.0	208.6	370.1	170.8	332.4	207.7	393.0	
A42	277.9	60.7	240.3	55.3	238.2	69.5	259.6	107.8	107.6	145.6	157.1	188.6	
A44	190.1	64.0	158.8	65.4	183.0	72.8	273.4	98.9	129.6	117.9	149.1	122.5	
A45	393.4	101.9	238.5	79.7	218.4	55.5	291.2	105.0	123.8	158.6	292.3	173.4	
A46													
A47													
A48													
A43	38.4	14.8	49.5	10.3	32.5	15.7	94.1	23.4	138.8	82.6	170.9	89.6	

eg	Fair Leg	Fair Leg	Fair Leg	Fair Leg	Good Leg	Good Leg	Good Curl	Good Curl	Good Curl	Good Curl	Good Curl	Good Curl	Good Leg	Good Leg	G
nal (E)	Internal (F)	External (F)	Internal (G)	External (G)	Internal (H)	External (H)	Internal (I)	External (I)	Internal (J)	External (J)	Internal (K)	External (K)	Internal (L)	External (L)	I
95.0	1.8	89.2	6.9	87.2	1.9	92.0									
211.9	93.5	220.6	92.7	234.4	81.0	155.8									
138.4	66.7	119.9	73.7	138.5	120.3	121.0									
78.3	90.9	81.2	110.5	78.7	134.5	79.7									
97.5	94.1	102.5	80.1	102.9	8.7	37.9									
241.3	288.5	269.9	235.7	247.8	225.3	280.9									
218.0	155.7	182.0	164.7	187.3	159.1	213.7									
21.4	140.6	37.4	155.8	55.7	209.9	29.8									
67.1	120.1	67.2	108.4	62.0	206.8	58.4									
135.2	67.6	133.7	79.1	152.0	88.3	160.6									
42.5	4.4	22.1	6.2	30.0	7.3	24.3									
69.6	119.0	70.0	42.9	70.8	115.5	85.1									
82.5	137.1	94.5	100.4	109.6	130.6	128.2									
217.4	2.6	268.3	2.3	169.9	3.3	138.1									
253.5	75.8	233.9	19.2	269.2	76.7	348.7									
122.4	156.7	132.9	310.4	139.9	296.6	199.6									
150.9	123.4	84.9	246.1	198.7	268.3	204.3									
221.3	104.7	180.9	138.3	195.4	173.7	257.3									
73.2	76.6	76.8	91.8	85.0	141.7	107.0									
233.8	197.7	293.6	136.3	208.3	373.0	421.6									
256.6	156.2	207.7	196.8	313.4	178.1	300.8									
195.1	71.4	170.1	68.4	193.4	7.7	120.1									
113.1	228.8	124.7	117.8	59.6	209.2	101.9									
130.6	99.2	134.2	124.5	162.6	139.3	173.7									
115.8	96.7	119.3	134.6	107.4	145.5	160.2									
66.0	301.4	39.8	226.1	73.3	440.3	81.5									
115.5	94.3	71.4	121.2	95.7	146.8	149.3									
200.4	294.3	206.7	236.7	177.9	402.0	270.1									
17.5	62.3	39.1	63.8	31.1	75.2	53.0									
155.1	261.6	142.8	207.7	148.2	331.9	175.9									
58.0	87.2	60.2	79.0	51.2	89.5	62.4									
136.2	141.8	102.7	133.0	118.6	173.5	176.6									
80.5	59.1	81.2	44.1	72.9	96.5	113.3									
239.0	343.9	214.0	264.8	218.9	331.9	188.9									
142.1	308.7	130.4	283.9	139.3	378.6	177.5									
337.6	129.0	274.4	195.0	384.4	211.7	347.5									
92.5	99.5	109.1	105.5	104.4	0.1	35.6									
74.0	133.6	89.1	258.0	89.8	190.8	20.4									
210.7	96.4	217.5	79.3	173.2	115.9	205.2									
84.7	101.3	91.0	33.0	90.4	112.7	122.4									
332.4	207.7	393.0	175.6	323.9	294.3	573.3									
145.6	157.1	188.6	140.6	221.6	190.2	210.9									
117.9	149.1	122.5	162.1	142.9	182.0	132.5	247.4	59.3	150.3	49.0	187.0	58.3	245.2	143.8	
158.6	292.3	173.4	253.7	157.7	285.1	164.7	261.8	80.5	268.2	86.1	418.6	90.7	331.8	169.0	
							104.0	21.7	104.6	26.1	120.9	20.1	93.7	65.9	
							88.0	48.7	76.4	37.1	67.3	37.4	87.5	113.8	
							101.4	61.1	71.7	64.1	94.4	74.4	65.4	89.0	
82.6	170.9	89.6	152.5	85.3	178.5	85.3									

eg	Good Curl	Good Curl	Good Curl	Good Curl	Good Curl	Good Curl	Good Leg	Good Leg	Good Leg	Good Leg	Good Leg	Good Leg
al (H)	Internal (I)	External (I)	Internal (J)	External (J)	Internal (K)	External (K)	Internal (L)	External (L)	Internal (M)	External (M	Internal (N)	External (N)
92.0												
155.8												
121.0												
79.7												
37.9												
280.9												
213.7												
29.8												
58.4												
160.6												
24.3												
85.1												
128.2												
138.1												
348.7												
199.6												
204.3												
257.3												
107.0												
421.6												
300.8												
120.1												
101.9												
173.7												
160.2												
81.5												
149.3												
270.1												
53.0												
175.9												
62.4												
176.6												
113.3												
188.9												
177.5												
347.5												
35.6												
20.4												
205.2												
122.4												
573.3												
210.9												
132.5	247.4	59.3	150.3	49.0	187.0	58.3	245.2	143.8	174.4	124.5	155.2	120.3
164.7	261.8	80.5	268.2	86.1	418.6	90.7	331.8	169.0	304.7	186.8	266.0	154.0
	104.0	21.7	104.6	26.1	120.9	20.1	93.7	65.9	52.8	125.4	79.5	105.0
	88.0	48.7	76.4	37.1	67.3	37.4	87.5	113.8	107.8	121.2	114.9	126.3
	101.4	61.1	71.7	64.1	94.4	74.4	65.4	89.0	90.4	123.2	58.6	107.1
85.3												

APPENDIX H.

Instructions To The Subject

INSTRUCTIONS TO THE SUBJECT

REBECCA:

* Hi, how are you?

* Please read and sign the consent form.

* Please pick up all cards in a random order and place in a pile, face down.

* Now you can stretch for a few minutes.

* When you feel stretched you can go over to Margie and she'll set you up with the electrodes.

MARGIE:

* You can lay down on your back with your head at this end. I need to prepare your skin with alcohol so please expose your right abdomen and just below your right hip bone (ASIS). The alcohol is a little cool. Now I need to draw a few landmarks on your skin for electrode placement. I will be applying a pair of electrodes, two over the internal oblique and two over the external oblique as well as a groundwire. Once the electrodes are in place Rebecca will guide you through the positions.

REBECCA:

* Before we begin each test I want you to have your stomach muscles relaxed.

* Margie will say "begin" and I will guide you into the position written on the

card we are on. Then I will say "hold" and Margie will count to five watching her stopwatch. I want you to count along with Margie, or just make sure to breath. We don't want you to be holding your breath, having a valsalva effect. Also, try not to use more muscle strength than you need; just exert as much as you need to. Some of these positions will be very easy for you.

After Margie counts to five, I'll say "relax," and "good," and you'll lay back down. Then you'll have one minute to relax. And we'll begin with the next card on the pile.

* Now we'll wait for Margie to say "begin".

MARGIE:

*"Begin".

REBECCA:

* For: 1. Trunk curl "fair." Arms out straight and point where the ceiling meets and wall. Curl up your head, and chest. There, and hold. Count, or breath, keep holding. Good! And relax.

* 2. Trunk curl "good." Arms across your chest, hands to elbows. Let your arms rest on your chest. Curl up your head, and chest. There, and hold. Count, or breath, keep holding. Good! And relax.

* 3. Leg-Lowering "fair+" and "good-." Arms across your chest. One knee up on

your chest, then the other. Straight legs up to the ceiling. Lower them enough to straighten your knees. And lower your legs slowly. There, and hold. Count, or breath, keep holding. Good! And relax.

MARGIE: during the Hold

* One one-thousand, two one-thousand, three one-thousand, four one-thousand, five one-thousand.

REBECCA:

* O. K! Good job! Margie will help you take off the electrodes, if you'd like. You did great. You can help yourself to a granola bar and juice when your ready. Thank you for helping us out!