Non-Predictability of Abdominal Strength and Function with Trunk Manual Muscle Testing in Patients with Low Back Pain

Eric C. Shamus
Lynn University

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Sponsoring Committee: Dr. Rita Nacken Gugel, Chairman,
Dr. Bernard Brucker, and
Dr. Fred Dembowski

Non-Predictability of Abdominal Strength and Function
with Trunk Manual Muscle Testing in Patients with Low Back Pain

Eric C. Shamus Ph.D., PT, CSCS

Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the College of Graduate Studies
Lynn University

2001
Non-Predictability of Abdominal Strength and Function with Trunk Manual Muscle Testing in Patients with Low Back Pain

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Acknowledgments

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Abstract

The purpose of this study was to determine the ability of the Clarkson and Gilewich manual muscle test of trunk flexion and rotation to predict abdominal muscle strength and function in patients with low back pain. In examining movement and function, physical therapists routinely test muscle strength.

The participants consisted of thirty-one adults with complaints of low back pain. For each subject, five tests were conducted. A manual muscle test of trunk flexion and rotation, dynamometer measurement of trunk flexion strength, and lumbar stabilization during a partial curl up and single leg slide were performed. Pearson product correlational statistics were calculated to test each hypothesis.

Analysis of the results revealed no significant correlation between any of the tests. In addition, test results did not significantly correlate with the subject’s pain level. Results of the study demonstrated that the manual muscle test of trunk flexion did not significantly correlate with actual abdominal strength. This clearly indicates that there is no predictive validity in using the trunk flexion manual muscle test to predict abdominal strength. The clinician that uses the trunk flexion manual muscle test for predicting actual abdominal muscle strength needs to reconsider this practice.

It is apparent that the trunk flexion or rotation manual muscle test cannot be used to the abdominal muscle’s ability to stabilize the lumbar spine. Stabilization is a complex neuromuscular skill. It appears that it can only be quantified through functional tests that measure an individual’s ability to maintain a neutral spine.
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Chapter 1

Introduction

Need for the Study

Physical therapists routinely test muscle strength because of its relationship to movement and function. The history of manual muscle testing dates back to 1912, when it was used to rate the loss of strength in infants with paralysis (Hislop & Montgomery, 1995). It has evolved into a strict set of guidelines through the contributions of many clinicians and scientists. Very few of the tests, however, have been substantiated by research.

Manual muscle tests are performed daily by physical therapists. Not only is it used to help predict a patient’s ability to function, it provides a reference with which to document progress. It is also routinely used to communicate progress with case managers, physicians and other therapists. Most importantly, physical therapists design a patient’s individualized rehabilitation program based on his/her performance during a manual muscle test.

Abdominal muscle strengthening exercises are frequently advocated by physical therapists in the treatment of patients with low back pathology (McGill, 1998; O’Sullivan, Twomey, & Allison, 1997; Shields & Heiss, 1997). Recent emphasis has been on their role in dynamic stabilization of the spine through co-contraction with the trunk extensors (Richardson & Jull, 1995). O’Sullivan et al. (1997) have found a statistically significant decrease in low back pain intensity and functional disability with a lumbar stabilizing
exercise program. Increasing a patient’s ability to stabilize the spine will not only maintain a healing environment; it will also help minimize future recurrences (Richardson & Jull, 1995). In order to develop the optimal rehabilitation program for patients with low back pathology, it is important to have a manual muscle test that can accurately predict abdominal muscle strength and function.

The Problem and Theoretical Framework

In examining movement and function, physical therapists routinely test muscle strength. When therapists evaluate patients with low back pathology, it is recommended that clinicians manual muscle test (MMT) abdominal strength (Hoppenfeld, 1976). Once strength has been assessed, abdominal muscle strengthening exercises are frequently advocated by physical therapists in the treatment of patients with low back pathology (McGill, 1998; Shields & Heiss, 1997). Recent attention has been on the role of the abdominals (rectus abdominis, external and internal oblique) in dynamic stabilization of the spine through co-contraction with the trunk extensors (O'Sullivan, et al., 1997; Richardson & Jull, 1995). In order to develop the optimal rehabilitation program for patients with low back pathology, it is important to have a manual muscle test that can accurately predict abdominal muscle strength and function.

Very few of the tests, however, have been adequately investigated by research. Consequently, it was the purpose of this study to determine the ability of the Clarkson and Gilewich manual muscle test of trunk flexion to predict abdominal muscle strength and function in patients with low back pain. Furthermore, this research investigated the
question of relevance of abdominal muscle strength testing as it relates to function in stabilizing and protecting the spine.

In reviewing the literature, researchers and clinicians are searching for valid and reliable means for testing abdominal strength. Ideally, several authors have utilized isokinetic equipment such as the Cybex and Kin Com to measure abdominal strength (Mayer, Smith, Keeley, & Mooney, 1985; Shirado, Ito, Kaneda, & Strax, 1995; Suzuki & Endo, 1983). Although this equipment is valid and reliable, it is extremely expensive and not available to the majority of clinicians.

Other researchers have designed their own testing protocols. For example, Helewa, Goldsmith, Smythe, and Gibson (1990) compared four different measures of abdominal strength: dynamometer to chest, dynamometer to knee, graduated sit ups, and blowing into a manometer. The authors determined that the dynamometer to the chest and knee were the most sensitive. In 1993, Helewa, Goldsmith, & Smythe compared a sphygmomanometer, a vigorometer, and a myometer. The authors concluded that all performed equally well.

Moreland, Finch, Stratford, Baslor, and Gill (1997) tested the reliability of six tests of static and dynamic endurance and isometric force. Only the dynamic endurance test of repeated sit ups was found to be highly reliable. None of these tests have been valid and practical enough to replace the printed classical manual muscle test of the late 1940s (Kendall & Kendall, 1949).

Trunk flexion in a supine position is the standard method for testing abdominal strength (Kendall & Kendall, 1949). Grading for performance is based on a numerical scale ranging from zero (0) to five (5). Each numerical grade can be compared with a
qualitative grade (word). A zero means no muscle activity, a one means trace muscle activity, a two means poor muscle activity, a three means fair muscle activity, a four means good muscle activity and a five means normal muscle activity. Additional grading increments of plus (+) or minus (-) can be used to designate strength performance slightly above or below the numerical grade provided (Hislop & Montgomery, 1995).

The textbook Musculoskeletal assessment: Joint range of motion and manual muscle strength is utilized by students and clinicians throughout the country (Clarkson & Gilewich, 1989). Smidt, Blanpied, Anderson, and White (1987) examined the sensitivity of this test for trunk flexion as compared to measurements taken by the Kin Com. They were unable to find a significant difference between any of the muscle grades on torque produced concentrically or eccentrically. Isometrically, they did find a difference between the group that received a five out of five and the group that was less than a three out of five. He concluded that the sit up test is not sensitive enough to meet the needs of clinicians. In critiquing this study, it is important to note that the sit ups were performed in the supine position and the Kin Com testing position is seated. It is possible that simply the change in position threatened the validity of the comparison. Through their research on the Kin Com, Shirado et al. (1995) demonstrated that changing the foot position could alter the torque produced. Smidt et al. (1987) also tested healthy subjects and subjects who had a history of back pain but no current symptoms. It can be argued that manual muscle testing was never intended to be used on individuals without a current injury.

Less expensive and more functional ways test the stability of the spine have also been researched. Gilleard and Brown (1994) used a child’s sphygmomanometer cuff
placed under the lumbar lordosis to measure pressure changes. This device is extremely low cost and available to clinicians in most clinics. O'Sullivan et al. (1997) proposed a stabilizing program with the use of a more specific pressure transducer biofeedback monitor (Chattanooga Australia Pty, Ltd., Brisbane, Queensland). It provided an objective biofeedback tool for correct activation of the spinal stabilization muscles by maintaining a constant pressure under the pelvis and lumbar spine. This is one of the only ways to determine objectively if the spine is not changing the neutral lordotic position with movement. Except for a fluoroscopy, which has a high amount of radiation and is not able to be performed by physical therapists, the pressure transducer is the most available option at this time.

Statement of the Purpose

The purpose of this study was to determine the ability of the Clarkson and Gilewich manual muscle test of trunk flexion and rotation to predict abdominal muscle strength and function in patients with low back pain. This was investigated by determining if a significant relationship exists between the Clarkson and Gilewich test and the strength values obtained by Helewa's dynamometer to sternum technique. The ability of the Clarkson and Gilewich tests for abdominal muscle strength to predict the ability of the patient to maintain a neutral spine was investigated. That is, did the Clarkson and Gilewich tests for abdominal muscle strength significantly correlate with a subject's ability to maintain a neutral spine while performing a particular activity?
Policy and Practical Implications

If the Clarkson and Gilewich test, Helewa's dynamometer to sternum technique, and the pressure transducer measurement during functional activities have no significant relationship, there are several implications to the evaluation of patients with low back pain. First, the standard muscle strength tests performed by therapists would provide false conclusions about the functional relationship. As such, alternate methods of assessing functional abilities of the abdominal muscles in their ability to stabilize the spine during functional activities would need to be investigated. Overall, therapists would have to rethink their method of assessment of the abdominals.

Definition of Terms

**Abdominal Muscle Function**- The subject's ability to automatically coordinate an optimal pattern of muscle activity to maintain the starting spine position in order to control postures and motions safely and effectively (Richardson et al., 1992)

**Abdominals**- Rectus abdominis, External and Internal Oblique

**Actual Abdominal Muscle Strength**- Defined by the dynamometer to chest technique previously described by Helewa et al. (1990)

**Concentric Muscle Contraction**- When the total tension developed in all the cross-bridges of a muscle is sufficient to overcome any resistance shortening (Baechle & Earle, 2000)

**Isometric Muscle Contraction**- When the tension in the cross-bridge equals the resistance of shortening, and the muscle length remains relatively constant (Baechle & Earle, 2000)
Stabilization - The ability to maintain a fixed position

Hypotheses

Hypothesis I.

There is no significant relationship between the trunk flexion manual muscle test grade and the dynamometer measurement of abdominal muscle strength.

Hypothesis II.

There is no significant relationship between the trunk flexion manual muscle test grade and the pressure transducer measurement of abdominal muscle function during a partial curl up.

Hypothesis III.

There is no significant relationship between the trunk rotation manual muscle test grade and the pressure transducer measurement of abdominal muscle function during a single leg slide.

Hypothesis IV.

There is no significant relationship between the trunk rotation manual muscle test grade and the pressure transducer measurement of abdominal muscle function during a partial curl up.
Hypothesis V.

There is no significant relationship between the dynamometer measurement of abdominal muscle strength and the pressure transducer measurement of abdominal muscle function during a partial curl up.

Hypothesis VI.

There is no significant relationship between the dynamometer measurement of abdominal muscle strength and the pressure transducer measurement of abdominal muscle function during a single leg slide.
Chapter 2

Review of Literature

Research shows that weakness of the trunk muscles in patients with low back pain in an out-patient setting and a hospitalized chronic pain center is prevalent. Addison and Schultz studied 23 patients with chronic low back disorders in a hospitalized chronic pain center and found that the patients have approximately 50% of the trunk strength of healthy subjects (Addison & Schultz, 1980). Furthermore, the trunk extensors were more affected than the flexors and proportionally, their anterior abdominal muscles were not weaker than other trunk muscles. McNeill, Warwick, Anderson, and Schultz (1980) utilizing the same healthy patients as Addison and Schultz (1980), compared the findings to a sample of 40 subjects with low back pain in an out-patient setting. Despite gender, the healthy subjects were 60% stronger in absolute trunk strengths when compared to their injured counterparts. The strength ratios examined also supported the notion that the trunk extensors are more affected than the flexors.

On the other hand, a study published in 1983, by Suzuki and Endo found a generalized weakness in the trunk muscles, but did not support the concept that an imbalance between the flexors and extensors existed (Suzuki & Endo, 1983). This study did not state how long the subjects had suffered from back pain. These two factors may have influenced their results.

In 1985, Mayer et al. (1985) utilized a new trunk strength tester on 286 patients with chronic low back pain (LBP). They were able to determine that patients with LBP had decreased strength of the flexors and extensors with greater variability than the
controls. Again, extensor strength was found to be more affected than flexor strength. They concluded that this trunk weakness is a major contributing factor in the deconditioning syndrome associated with LBP.

Research by Takemasa, Yamamoto, and Toshikazu (1995) went a step further. Not only did they examine trunk strengths in patients with chronic LBP, they compared the response of subjects with and without organic lesions in response to exercise programs (Takemasa et al., 1995). Trunk flexor and extensor strengths were lower for both groups with LBP. However, the group without an organic lesion had a higher correlation of improved trunk strength and decreased pain with exercise. Their results suggest that the cause of LBP may be a determining factor in weakness and response to treatment.

In 1995, Shirado et al. (1995) investigated the phenomenon of trunk strength in patients with chronic LBP. They investigated if testing position can affect the torques produced. Their research supports that weakness exists in the trunk strength of subjects with LBP. Furthermore, they also noted that testing posture has a significant influence on strength values. Trunk strength was significantly higher in a sitting posture with the feet fixed on the floor.

In order for physical therapists to objectively quantify abdominal muscle strength weakness in the clinic, it is important to have reliable and valid tests. All of the studies noted above utilized specialized and expensive equipment to quantify strength. It is important to have a method that can be performed in any clinic without special equipment. The accepted standard for testing muscle strength is manual muscle testing
(Addison & Schultz, 1980). Unfortunately, few of the manual muscle tests are supported by research.

Several authors believe that fundamentally, the manual muscle test does not specify a range of strength, it determines the presence of weakness (Hislop & Montgomery, 1995; Kendall & McCreary, 1993). The ability of the tester to provide enough force to determine this weakness is also a limiting factor (Beasley, 1961). Research conducted by Perry, Fontaine, and Mulroy (1995) studied patients with poliomyelitis. They found that a perfect grade, 5/5, actually corresponded with 50 to 59% of maximal strength. A 4/5 grade was associated with 40% strength and a 3+/5 grade was associated with 25% strength.

Problems with reliability have also been found. Frese, Brown, and Norton (1987) researched the reliability of manual muscle testing for the middle trapezius and the gluteus medius muscles. One hundred ten subjects were tested by eleven physical therapists with varying years of experience. They concluded that the interrater reliability is low for these two manual muscle tests. For each muscle, only 50 to 60% of the time did the clinicians arrive at the same grade or within 1/3 grade of each other. Another study examined reliability of manual muscle testing on 174 muscles in the body. Intrarater reliability was high, with grades falling within one of each other 96 to 98% of the time. However, interrater reliability was found to be poor. Therapists were only in agreement 42 to 51% of the time.

It is evident that the manual muscle testing system may need to be improved. Many authors have investigated improved methods to test abdominal strength without utilizing specialized equipment. Smidt et al. (1987) examined three techniques: a sit up,
prone extension and double leg lowering on patients with LBP. Each technique has specific grading criteria established. They discovered that the majority of subjects had no difficulty achieving the highest grade on the sit up and prone extension tests. The double leg lowering techniques was better able to detect weakness, but only in a broad range. They concluded that none of the tests were sensitive enough to test trunk muscle strength.

Helewa et al. (1993) and Helewa et al. (1990) performed studies to test seven different evaluative techniques for abdominal strength. The first, in 1990, the authors compared four techniques: dynamometer to knee, dynamometer to sternum, graduated sit-ups and blowing into a manometer (Helewa et al., 1990). They found that the dynamometer to knee and dynamometer to sternum methods were equally sensitive. They recommended that clinicians use the dynamometer to sternum techniques because it was comfortable for the patient. A second study compared the dynamometer to sternum method to a vigorometer and a myometer (Helewa et al., 1993). All instruments were accurate, however the dynamometer is the least expensive and therefore recommended for clinical use.

Moreland et al. (1997) agree that feasible tests for trunk strength are needed in the clinic. They studied six tests of abdominal and extensor muscle strength and endurance. Only the dynamic endurance tests were found to be reliable. These tests involved asking the subjects to perform as many sit ups and prone extensions as possible while the examiner counted the repetitions. One major problem with this study is that the subjects had no history of LBP. It can be argued that manual muscle tests are only intended to be used on a symptomatic population.
Although a few researchers have studied various sit up techniques for measuring abdominal strength, none of them followed the manual muscle test guidelines that are utilized in most clinics. In the Clarkson and Gilewich book, *Musculoskeletal assessment: Joint range of motion and manual muscle strength* (1989), the subject is placed in a supine hooklying position and is expected to posteriorly tilt the pelvis and raise the head, neck and trunk off the table. The position of the arms creates a difference in resistance, which results in different muscle strength grades. The Smidt article also places the subject in supine hooklying and uses arm positions to provide resistance (Smidt et al., 1987). There is no mention of a posterior pelvic tilt. Furthermore, they are testing the validity of this test as compared to an isokinetic machine. This testing position is in sitting with the feet fixed to the floor. As mentioned earlier, Shirado et al. (1995) found that testing position can alter the amount of force that can be produced. The Moreland group also examined a similar sit up technique but used it to quantify endurance and not strength (Moreland et al., 1997). So the question remains, is the sit up technique in the Clarkson and Gilewich text a reliable test for rectus abdominus strength?

The Moreland article is one of the first to go beyond examining abdominal strength and to consider endurance (Moreland et al., 1997). The issue is, what is the role of the muscles and how can it best be quantified. This information is essential to the therapist who is going to design a plan of care and treatment for a patient with LBP. The current belief is to rehabilitate the spine to not only increase the torque producing capabilities of the large trunk muscles, but to reeducate the patient’s ability to automatically coordinate an optimal pattern of muscle activity to control postures and functions safely and effectively (Jull, Richardson, Toppenberg, Comerford, & Bui, 1993).
Traditional techniques for treating patients with LBP are being refuted and replaced with new ones. Clinicians in the past have advocated teaching a posterior pelvic tilt to provide stabilization of the spine. Researchers have demonstrated that a posterior pelvic tilt preloads the annulus and posterior ligaments of the spine, which can be detrimental to the healing process (McGill, 1998; Richardson, Jull, Toppenberg, Comerford, & Bui, 1992). A posterior pelvic tilt also generates high pressures in the spine and places it in extreme flexion. The alternative method is to promote a neutral spine posture. This position minimizes passive tissue forces by avoiding hyperlordotic and hypolordotic postures. This reduces the pressures in the spine and reduces the risk of injury.

The principle of neutral spine recognizes that some muscles have a greater role in stabilizing the spine than others. Trunk muscles such as the oblique abdominals and the deep transverse abdominus have key roles in spinal support and control (Jull & Richardson, 1994). The internal and external oblique abdominals act in synergy with the multifidus and quadratus lumborum to provide rotary control of the trunk. Large muscles such as the rectus abdominus and the erector spinae are located too far away from the spine to stabilize it. Consequently, they are considered prime movers of the spine.

Research indicates that after a back injury, there are problems with this stabilizing mechanism (Hides, Richardson, & Jull, 1996; Jull & Richardson, 1994; Richardson & Jull, 1995). Hides et al. (1996) discovered that after a first episode of LBP, subjects have poor spontaneous recovery of function of the multifidus muscles. Therefore, the therapist must use exercises to focus on retraining a precise co-contraction pattern of the deep
trunk muscles (Richardson & Jull, 1995). Dynamic spinal stabilization is a complex neuromuscular skill (Jull & Richardson, 1994). The patient must be taught to coordinate muscle function with activities of daily living. Repetition of proper movements enhance the neurophysiologic process of learning this technique. Therapists teach abdominal bracing to assist patients in maintaining neutral spine. This technique helps patients to recruit the obliques and not the rectus abdominus (Jull et al., 1993).

The question then arises, do we quantify and objectify the ability of a patient to maintain neutral spine and recruit the appropriate muscles in the process. Jull et al. (1993) proposed a static model utilizing a pressure cell. They made the assumption that excessive lumbar motion indicates the lack of spinal stabilization. They consequently designed a computerized sensor to detect lumbar movement. Electromyography was utilized to detect which muscles were being recruited. They found that this tool could reliably detect a lack of rotary stability when a load was applied in the sagittal plane.

Gilleard and Brown (1994) created an abdominal muscle test similar to the pressure transducer by Jull et al. (1993). They used a child’s sphygmomanometer cuff placed under the lumbar lordosis to measure pressure changes. Grades were assigned based on the ability to stabilize the spine during difference activities designed to challenge the abdominal muscles. The authors concluded that their technique was a reliable way to assess abdominal muscle function. The one limitation of the study is that they required the subjects to maintain a posterior pelvic tilt. As mentioned previously, this is not the position of choice when rehabilitating the spine. Determining if there is a significant relationship between different abdominal tests and function will provide therapists objective information about components of spinal stability.
Chapter 3

Methods

Study Design

This was a prospective experimental study. Institutional Review Board (IRB) approval was obtained from Lynn University.

Subjects

Thirty-one subjects who were receiving treatment at an outpatient orthopedic physical therapy clinic and a chiropractic clinic for complaints of low back pain were utilized. All individuals receiving care for their low back on this day were asked by the treating clinician if they would be willing to participate in this research. Exclusion criteria included cardiopulmonary risk factors, abdominal or back surgery in the past eight weeks (many times the testing motion are contraindicated because of the stress on the scar), subjective pain scale rating of greater than 5/10, trunk flexion manual muscle test grade of less than 3 out of 5, other injuries at the time of testing, limitations in the upper extremity or lower extremity ranges of motion that would make the subject unable to assume the testing positions, patients whose therapy was covered by worker’s compensation or if an attorney was involved, and patients who have attended therapy before and learned abdominal stabilization. Participants signed a consent form before beginning the study. Each subject was given a number and no names were recorded with the data to maintain confidentiality. Data were recorded on the data collection form (see Appendix G). Subjects ranged in age from 20 to 50 years old. The mean age of the...
subjects was 34.81 years (S.D. = 8.46) (see table 1). There were seventeen females and fourteen males. Each subject complained of low back discomfort ranging from zero to five on a pain scale of zero to ten.

Table 1.

Subject's Mean, Range and Standard Deviation of Age

<table>
<thead>
<tr>
<th>N#</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
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<tbody>
<tr>
<td>31</td>
<td>20.00</td>
<td>50.00</td>
<td>34.81</td>
<td>8.46</td>
</tr>
</tbody>
</table>

In examining the populations studied for abdominal strength, certain variables need to be considered. Gender and race/ethnicity does not have a significant effect on abdominal strength (Addison & Schultz, 1980; McNeill et al., 1980). The weight of the subject can make a difference, but was accounted for. The age of the subject can also have an effect on abdominal testing. Spinal mobility decreases with age. Prior to age 20, the spine is extremely flexible and not often injured. After age 50, the vertebral discs become more fibrous and decrease vertebral space (Saunders & Saunders, 1995).

When selecting a population size, one needs to consider the size of the effect and the within variance of the population. Since low back pain is such a variable diagnosis and covers many different injuries, a large population would be best. McNeill et al. (1980) utilized 40 healthy subjects to assess trunk strength, while Addison and Schultz (1980), compared the findings to a sample of 40 subjects with low back pain in an out-
patient setting. These two studies were important because it was demonstrated that with samples of at least 40 subjects, significant abdominal strength differences could be found. Significance could be established with 40 subjects.

Instruments

The trunk flexion manual muscle test referred to in this paper was performed as described in the textbook *Musculoskeletal assessment: Joint range of motion and manual muscle strength* (see Appendixes A, B, and C) (Clarkson & Gilewich, 1989). Subjects were placed supine in the crook lying position and asked to raise the trunk off the table to a 45 degree angle (Phase 1 - rectus abdominus). Positioning of the arms acts as resistance. Subjects received a grade of 1 to 5 based on their performance.

The trunk rotation manual muscle test referred to in this paper was performed as described in the textbook *Musculoskeletal assessment: Joint range of motion and manual muscle strength* (see Appendixes D, E, and F) (Clarkson & Gilewich, 1989). Subjects were placed supine with the knees flexed and asked to raise the trunk and rotate the shoulder toward the opposite knee. Subjects were assigned a grade of 3, 4 or 5 depending on the position of the arms and the ability to flex their trunk off the table to a 45 degree angle.

For the purpose of this paper, actual abdominal muscle strength was defined by the dynamometer to chest technique previously described by Helewa et al. (1990). The dynamometer utilized in this study was the Chatillon Hand Held Dynamometer (John Chatillon and Sons, Inc., 7609 Business Park Drive, Greensboro, North Carolina 27409,
The results were reported as the change in millimeters of mercury during execution of the test.

Abdominal muscle function was defined as the subjects ability to automatically coordinate an optimal pattern of muscle activity to maintain the starting spine position in order to control postures and motions safely and effectively. It was measured by placing a blood pressure cuff (pressure transducer) under the lumbar spine as described by Richardson et al. (1992). Correct activation of the corresponding musculature registers as a ten millimeter (mm) of Mercury (Hg) increase and stabilization was defined by the ability to maintain constant pressure throughout the activity. Preliminary results point toward high reliability and validity of this technique. The results were reported as the change in millimeters of mercury during execution of the test.

Procedure

The tester was a physical therapist with nine years experience. The therapist was trained in the techniques and allowed to practice with the procedures. Each subject started by filling out a questionnaire that asked about their age, past medical history, subjective pain level, and if they had participated in any exercise training for their abdominal muscles in the past three months. Subjects then underwent a series of randomized tests.

Test 1: Manual Muscle Test of Trunk Flexion.

Subjects were placed crook lying as described in the Clarkson and Gilewich book (1989) with their hands behind their head. For this study, hips were flexed to 30 degrees and knees to 90 degrees. Subjects were instructed to: Tuck your chin and bring your
head, shoulders and arms off the table as in a sit up (Grade 5). If the subject was unable
to rise off the table to a 45 degree angle, the test was repeated with the arms crossed
across the chest (Grade 4). If still unable to complete the test, the arms were extended
forward (Grade 3). The tester recorded a grade from three to five (see Appendixes A, B,
and C).

**Test 2: Manual Muscle Test of Trunk Rotation.**

Subjects were placed crook lying as described in the Clarkson and Gilewich book
(1989) with their hands behind their head. For this study, hips were flexed to 30 degrees
and knees to 90 degrees. Subjects were instructed to: "Lift your head and shoulders from
the table, taking your right elbow toward your left knee. Now lift your head and
shoulders from the table, taking your left elbow toward your right knee (Grade 5)." If the
subject was unable to rise off the table to a 45 degree angle, the test was repeated with the
arms crossed across the chest (Grade 4). If still unable to complete the test, the arms
were extended (Grade 3). The tester recorded the grade from three to five (see
Appendixes D, E, and F).

**Test 3: Dynamometer to Chest Strength Test.**

The subjects were placed supine with the hips flexed to 30 degrees and the knees
flexed to 90 degrees with the feet strapped to the plinth as described in the 1990 Helewa
et al. article. Subjects were assisted in raising the head and shoulders off the table to
achieve a position where the C7 spinous process is 20 cm from the plinth. The
dynamometer was placed just caudal to the supra sternal notch at a 90 degree angle
within line of the force on the subject. Subjects were allowed 1 to 2 seconds to come to
maximal effort. The test was then held for 4 to 5 seconds. The subject was asked to maintain this position as the tester removed their support. Subjects were instructed to: "Hold this position against my pressure and as I gradually increase the pressure, try to match it. At the count of two, I will be exerting maximal pressure. Now, hold that position one and two and .... five and now hold a little while longer." The tester recorded the maximum strength from the dynamometer in foot-pounds.

Test 4: Partial Curl Up Functional Test.

The subjects were placed supine with their hips flexed to 90 degrees and their knees flexed to 70 degrees, hands behind their head with the pressure transducer placed behind the spine from L1 to S2. The pressure transducer was inflated to 40 mm of Hg and the subjects were instructed to: "Contract your abdomen by drawing the navel up and in toward the spine so as to hollow out your abdomen. Do not forget to breathe while you perform this maneuver." Subjects were allowed to practice once. "Now I want you to contract your abdomen to stabilize your spine and now lift your head, shoulders and arms off the table as in a sit up, hold for two seconds and then return to your starting position." The tester recorded the starting pressure, pressure at the high point and ending pressures from the gauge.

Test 5: Single Leg Slide Functional Test.

Subjects were placed supine with their hips flexed to 30 degrees and their knees flexed to 90 degrees, arms at their side with the pressure transducer placed behind the spine from L1 to S2. The pressure transducer was inflated to 40 mm of Hg and the subjects were instructed to: "Contract your abdomen by drawing the navel up and in
toward the spine so as to hollow out your abdomen. Do not forget to breathe while you perform this maneuver." Subjects were allowed to practice once. "Now I want you to contract your abdomen and slide your right heel down the table until your knee is straight. Hold that position for two seconds and return to your starting position. Now repeat the procedure with your left heel." The tester recorded the pressure scores from the gauge for both legs at the beginning, knee straight and return position.

All subjects received a one minute rest between the tests.

Data Analysis

Pearson product correlational statistics were performed to test each hypothesis. To determine the effect of pain on muscle strength, post hoc analyses were performed to determine if there was a significant correlation of each test and the subject's pain level. A Pearson product correlation was performed each on the 5 tests and the subject's pain level.
Chapter 4

Results

In order to test hypothesis I, which states that there will be no significant relationship between the trunk flexion manual muscle test grade and the dynamometer measurement of abdominal muscle strength, a Pearson product correlation was performed. No significant relationship was found \( (r = .112, p > .05) \). This supports the hypothesis. The mean and standard deviation for the MMT test and dynamometer test of strength are reported in Table 2.

In order to test hypothesis II, which states that there is no significant relationship between the trunk flexion manual muscle test grade and the pressure transducer measurement of abdominal muscle function during a partial curl up, a Pearson product correlation was performed. No significant relationship was found \( (r = .234, p > .05) \). This supports the hypothesis. The mean and standard deviation of the MMT test and the change of pressure measured in foot-pounds are reported in Table 2.

In order to test hypothesis III, which states that there is no significant relationship between trunk rotation manual muscle test grade and the pressure transducer measurement of abdominal muscle function during a single leg slide, a Pearson product correlation was performed. No significant relationship was found \( (r = -.053, p > .05) \). This supports the hypothesis. The mean and standard deviation of the MMT test and the change of pressure measured in foot-pounds are reported in Table 2.
Table 2.

Mean and Standard Deviations for Abdominal Tests

| Test 1: Manual Muscle Test of Trunk Flexion | MMT OF TRUNK FLEXION |
| Test 2: Manual Muscle Test of Trunk Rotation | MMT OF TRUNK ROTATION |
| Test 3: Dynamometer to Chest Strength | DYNAMOMETER TO CHEST |
| Test 4: Partial Curl Up Functional Test | PARTIAL CURL UP |
| Test 5: Single Leg Slide Functional Test | SINGLE LEG SLIDE |

In order to test hypothesis IV, which states that there is no significant relationship between the trunk rotation manual muscle test grade and the pressure transducer measurement of abdominal muscle function during a partial curl up, a Pearson product correlation was performed. No significant relationship was found ($r = .211, p > .05$). This supports the hypothesis. The mean and standard deviation of the MMT test and the change of pressure measured in foot-pounds are reported in Table 2.
In order to test hypothesis V, which states that there is no significant relationship between the dynamometer measurement of abdominal muscle strength and the pressure transducer measurement of abdominal muscle function during a partial curl up was performed. No significant relationship was found ($r = -.065$, $p > .05$). This supports the hypothesis. The mean and standard deviation of the dynamometer test and the change of pressure measured in foot-pounds are reported in Table 2.

In order to test hypothesis VI, which states that there is no significant relationship between the dynamometer measurement of abdominal muscle strength and the pressure transducer measurement of abdominal muscle function during a single leg slide, a Pearson product correlation was performed. No significant relationship was found ($r = .079$, $p > .05$). This supports the hypothesis. In Table 2, the mean and standard deviation of the dynamometer test and the change of pressure measured in foot-pounds are reported.

Table 3.

Pearson Product Correlation Results For Hypotheses

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Measurement Comparison</th>
<th>Correlation</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothesis I</td>
<td>MMT of Trunk Flexion and Dynamometer</td>
<td>$r = .112$, NS</td>
<td></td>
</tr>
<tr>
<td>Hypothesis II</td>
<td>MMT of Trunk Flexion and Partial Curl Up</td>
<td>$r = .234$, NS</td>
<td></td>
</tr>
<tr>
<td>Hypothesis III</td>
<td>MMT of Trunk Rotation and Single Leg Slide</td>
<td>$r = -.053$, NS</td>
<td></td>
</tr>
<tr>
<td>Hypothesis IV</td>
<td>Trunk Rotation MMT and Partial Curl Up</td>
<td>$r = .211$, NS</td>
<td></td>
</tr>
<tr>
<td>Hypothesis V</td>
<td>Dynamometer and Partial Curl Up</td>
<td>$r = -.065$, NS</td>
<td></td>
</tr>
<tr>
<td>Hypothesis VI</td>
<td>Dynamometer and Single Leg Slide</td>
<td>$r = .079$, NS</td>
<td></td>
</tr>
</tbody>
</table>
Pearson product correlations were also performed to determine if there was a significant correlation between abdominal function and the subject's pain level. For the dynamometer to chest measurement and the subjective pain level, there was no significant correlation ($r = -0.393, p > 0.05$). For the functional leg slide and the subjective pain level, there was no significant correlation ($r = 0.111, p > 0.05$). For the functional curl up and the subjective pain level, there was no significant correlation ($r = -0.227, p > 0.05$). For the flexion manual muscle test and the subjective pain level, there was no significant correlation ($r = -0.139, p > 0.05$). For the rotation manual muscle test and the subjective pain level, there was no significant correlation ($r = -0.185, p > 0.05$).
Chapter 5

Discussion

No significant correlation was found between the trunk flexion manual muscle test grade and the dynamometer measurement of abdominal muscle strength. Results of the study have shown that the manual muscle test of trunk flexion grade does not significantly correlate with actual abdominal strength. This clearly indicates using the manual muscle test of trunk flexion and assuming it predicts is false. The clinician that uses the trunk flexion manual muscle test for predicting actual abdominal muscle strength really has a poor understanding of its true predictability and is done on a false understanding of the relationship. The manual muscle test of trunk flexion has no predictive ability.

The lack of a significant relationship could be secondary to the type of muscle contraction that was tested. The manual muscle test consists of a concentric muscle contraction and the dynamometer to chest tests isometric strength. An isometric contraction occurs when the tension in the cross-bridge equals the resistance of shortening, and the muscle length remains relatively constant. In the dynamometer to chest test of the abdominals, the movement of the pelvis was held constant and the abdominals balance the resistance to the pelvis. A concentric muscle contraction occurs when the total tension developed in all the cross-bridges of a muscle is sufficient to overcome any resistance shortening (Baechle & Earle, 2000). In the MMT for the abdominals, the cross-bridges in the rectus abdominus overcome the resistance of lifting the trunk against gravity. This also brings about the theory of specificity. DeLorme first
described this term in 1945. This refers to the method of training in a specific manner to produce a specific adaptation or training outcome. This is the same as the acronym SAID, specific adaptation to imposed demands. That is, the type of demand placed on the body dictates the type of adaptation that will occur. There should be an attempt to activate or recruit the same motor units as the activity requires. Incorporating training or testing that mimic the movement pattern desired, increases the likelihood that the muscles involved will be recruited (Baechle & Earle, 2000). However, it is also possible that the manual muscle test is not sensitive enough. This is supported by Frese et al. (1987) who concluded that the only 50 to 60% of the time clinicians arrived at the same manual muscle test grade or within 1/3 grade of each other.

No significant correlation was found between the trunk flexion manual muscle test grade and the pressure transducer measurement of abdominal muscle function during a partial curl up. The trunk flexion manual muscle test examines the ability of the abdominals to contract to raise the body, but not their ability to stabilize the lumbar spine. The pressure transducer test examines the ability of the abdominal muscles to flex the trunk while stabilizing the lumbar spine. This is consistent with Jull and Richardson (1994) who recognize that the rectus abdominus is located too far away from the spine to stabilize it. Consequently, the trunk flexion manual muscle test is not a good tool for the clinician to use to determine an individual's ability to stabilize the lumbar spine during a curl up. Jull and Richardson (1994) and Hides et al. (1996) suggest that it is a combination of the deep abdominal muscles, internal oblique, transverse abdominis, and the lumbar multifidi, provide dynamic stability and segmental control of the spine.
No significant correlation was found between the trunk rotation manual muscle test grade and the pressure transducer measurement of abdominal muscle function during a single leg slide. The external obliques, which can function as stabilizers of the lumbar spine, cannot be tested by manual muscle test to predict their ability to stabilize the lumbar spine during a single leg slide. Again, the difference is that you are testing a concentric contraction and trying to equate it with an isometric function. It is also possible that the muscles responsible for stabilization are the transverse abdominus and the multifidus, which could not be detected in the rotational manual muscle test.

Research conducted by Hodges and Richardson (1996) found that these muscle groups are the first to contract when the arm is raised or the leg is moved. Additionally, these muscle recruitment patterns are impaired in patients with low back pain (Hodges & Richardson, 1997). McGill (1988) also proposed the functional importance of the quadratus lumborum in spinal stabilization as this muscle's activity is associated with lumbar sagittal movement and compression.

No significant correlation was found between the trunk rotation manual muscle test grade and the pressure transducer measurement of abdominal muscle function during a partial curl up. As discussed previously, the rotational manual muscle test is a test of concentric function and does not significantly correlate with an isometric spinal stabilization.

No significant correlation was found between the dynamometer measurement of abdominal muscle strength and the pressure transducer measurement of abdominal muscle function during a partial curl up. This test compares static isometric abdominal strength for flexion with dynamic isometric abdominal strength for spinal stabilization.
There was no significant correlation with the ability to create flexion torque when compared to stabilization of the spine with extremity movement.

No significant correlation was found between the dynamometer measurement of abdominal muscle strength and the pressure transducer measurement of abdominal muscle function during a single leg slide. Even though they are both isometric contractions, the contraction of the abdominals in a static flexed posture does not predict their ability to dynamically stabilize in neutral. O'Sullivan et al. (1997) found that subjects with low back pain had higher EMG activity in the rectus abdominis compared to the internal oblique muscles in comparison to the normal matched patients. The findings of the O'Sullivan study support the reason why no significant correlation was found between the dynamometer and pressure transducer by showing that the prime mover (rectus abdominis) is often stronger than the trunk stabilizers (internal oblique) in patients with low back pain.

**Implications**

It is apparent from these analyses that it is not abdominal muscle strength, whether quantified by a manual muscle test or dynamometer, that clinicians should use to predict the ability of the individual to stabilize the lumbar spine. This is a major change in philosophy for health care professionals. Stabilization is a complex neuromuscular skill (Jull & Richardson, 1994). It can only be measured through functional tests that measure the individual’s ability to maintain a neutral spine.

Even though previous research found that individuals with pain may have an impaired ability to stabilize the spine secondary to slow muscle recruitment (Hodges &
Richardson, 1999), the results of this study demonstrated that pain is not a variable affecting the validity of the abdominal tests. Pain can impair function, but not a measurement in a clinical setting. It is probably not the pain as an independent factor that affects the test.

The functional tests performed in this study were in a supine position in order to use a pressure transducer. The author recognizes that individuals do not spend the majority of their day in a supine position. They need to be able to stabilize the spine during all their activities of daily living.

**Recommendations**

Previous studies have supported that patients can decrease their pain and dysfunction with stabilization training. Future studies need to examine a way to quantify an individual's ability to stabilize the spine while lifting, reaching or even while playing sports and the effect on pain and dysfunction. In addition, research should investigate an individual's ability to stabilize individual segments that are hypermobile. Perhaps keeping the spine in a neutral position is not needed as long as the individual segments move the proper amount and the normal biomechanics of the spine, including proper sequential muscle firing, are restored after injury.

**Limitations**

In this study, the correlation between abdominal strength and the ability to stabilize the lumbar spine did not reach significance. Perhaps a larger sample may reach significance. Considering the low correlation with this sample size, it would probably not
reach significance with a larger sample. Because of the importance of this study, a large sample may be appropriate.

In this study, weight was not identified as a specific variable. The weight of the subject can make a difference, but was not accounted for in this study. The effect on significance is not known. None of the subjects were noted to be obese or anorexic.

Age is a factor in the progression of changes in the spine. The standard deviation was found to be low and did not have a large within variance. This was an initial attempt for correlation. A follow up study with larger resources may include different age levels. These limitations must be considered in any detailed interpretation of the results.
References


Appendixes
Appendix A

Figure A1.

Grade 3 for Manual Muscle Test for the Rectus Abdominis

Appendix B

Figure B2.

Grade 4 for Manual Muscle Test for the Rectus Abdominis

Figure C3.

Grade 5 for Manual Muscle Test for the Rectus Abdominis

Appendix D

Figure D4.

Grade 3 for Manual Muscle Test for Trunk Rotation

Appendix E

Figure E5.

Grade 4 for Manual Muscle Test for Trunk Flexion

Figure F6.

Grade 5 for Manual Muscle Test for Trunk Flexion

Data Collection Form

MALE

FEMALE

AGE

Subjective Pain Level
0 1 2 4 5 6 7 8 9 10

Date of Injury

Current Symptoms

Trunk Flexion Manual Muscle Test 1 2 3 4 5
Trunk Rotation Manual Muscle Test 1 2 3 4 5
Dynamometer Strength for Trunk Flexion in foot-pounds

Functional Curl Up Start# Flexion#

Single Leg Slide Right Start# Out#

Left Start# Out#

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