The Effects of Abdominal Strength Exercises and Testing on Posture in School Children

Greta L. McDonald  
*Grand Valley State University*

Kristin L. Nederveld  
*Grand Valley State University*

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THE EFFECTS OF ABDOMINAL STRENGTH EXERCISES AND TESTING ON POSTURE IN SCHOOLCHILDREN

By

Greta L. McDonald
Kristin L. Nederveld

THESIS

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THE EFFECTS OF ABDOMINAL STRENGTH TESTING AND EXERCISE ON POSTURE IN SCHOOLCHILDREN

ABSTRACT

The purpose of this study was to compare an abdominal strength testing method used in school systems to tests used in the physical therapy profession. Results were associated with lumbar lordosis. The study included 58 female and 5 male subjects between 10-11 years old from two school districts. Kendall’s Upper Abdominal Test, Kendall’s Lower Abdominal Test and The Presidential Physical Fitness Test were performed in random order. Lumbar lordosis was measured before and after abdominal testing by recording the curvature of the low back using a flexible ruler. A Chi-square analysis was used to demonstrate the association of abdominal strength and lumbar lordosis. No statistical significance was found between the Presidential Physical Fitness Abdominal test and the Kendall Lower Abdominal test to the degree of lumbar lordosis. No statistical significance was determined between the Kendall Lower Abdominal test and the Presidential Physical Fitness Abdominal test.
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PREFACE

Operational Definitions

*ability to follow directions-* is defined as the ability to perform all tasks required with less than 3 explanations or demonstrations.

*general health-* is not having an illness/infection/injury which required that the student be absent from school within the last week.

*Kendall’s Lower Abdominal Test-* is a test used to evaluate lower abdominal strength; subjects lie supine on a firm surface with arms folded across the chest; a tester assists in raising the legs up to a vertical position (subjects may actively raise one lower extremity at a time if needed) keeping the knees straight; subjects then perform a posterior pelvic tilt and maintain this position while slowly lowering the legs to horizontal; strength is graded on the ability to keep the low back flat on the surface; the angle at which the back arches is noted and correlated with Kendall’s grading system (Kendall et al., 1993).

*Kendall’s Upper Abdominal Strength Test-* is a test of upper abdominal strength; subjects are asked to lie supine on firm surface with knees extended; a roll is place under the knees if the subject displays a positive Thomas Test; the subject is then asked to place both hands behind the head and proceed to slowly curl up to a sitting position completing spinal flexion range of motion; if this action can not be
achieved, the subject modifies the arm positions and a grade is assigned according to Kendall’s muscle grading system (Kendall et al., 1993).

*low back pain*—is defined as any pain and/or discomfort presently occurring in the low back region or a previous episode with a duration greater than 3 days within the last school year that required prolonged rest or medical attention.

*lower extremity pathologies*—is defined as any pelvic, hip, knee, ankle, or foot condition in the last year that required medical attention.

*lumbar lordosis*—is characterized by an increased lumbosacral angle (greater than 30°), an increased anterior pelvic tilt, and hip flexion; the following structures are elongated and weak: anterior abdominals (rectus abdominis, internal and external obliques); hamstrings may lengthen initially but after some time shorten to compensate for the posture; the following structures are short and strong: hip flexors (*iliopsoas*, *tensor fascia latae*, and *rectus femoris*), and lumbar extensors (*erector spinae*) (Kendall et al., 1993; Kisner & Colby, 1990).

*lumbosacral angle*—is the angle that the superior border of the first sacral vertebral body makes with the horizontal plane, which is optimally is 30° (Kisner & Colby, 1990).

*Manual Muscle Test*—is defined as a manual technique for estimating the relative strength of specific muscles; rating categories include normal, good, fair, poor, trace, and zero, based on active movement against resistance or evidence of contractility (Davis, 1989).
posterior pelvic tilt- is defined in which the vertical plane through the anterior-superior spines is posterior to the vertical plane through the symphysis pubis (Kendall et al., 1993).

Presidential Physical Fitness Abdominal Test- is a test used in school systems on 6-17 year olds to assess abdominal strength; students begin with knees flexed to 90° with feet no greater than 12 inches from the buttocks; the arms are held across the chest with the back flat against the floor; the feet are held by another and the student is instructed to curl the trunk so that the elbows touch the thighs and return back down so the scapulas touch the floor as many times as possible within 60 seconds; the test begins with the command “go” and terminates with “stop” (President’s Council on Physical Fitness and Sports, 1985).

Sit-up- is defined as the movement of coming from a supine to a sitting position by flexing the hip joints (Kendall et al., 1993).

spinal pathologies- consists of any of the following: scoliosis, disc herniation, Scheuermann’s disease, juvenile kyphosis, spinal tumors, and vertebral epiphysitis (Brashear & Raney, 1986).

90-90 Straight Leg Raising Test- is a measuring tool used to assess hamstring length; the test consists of the participant flexing the hip to 90° with the knees bent, with both hands, the subject grasps behind the knees to stabilize the hip position; the subject then actively extends each knee through full range of motion; knee extension should be within 20° of full extension to be considered normal (Magee, 1992).
Thomas Test— is based upon the participants’ inability to extend the hip without producing a lordosis; if a flexion deformity is present at the hip, the patient is unable to extend the thigh, and it remains at an angle (Jones & Lovett, 1929); the test is administered by asking a patient in the supine position with legs extended to bring one to their chest and the contralateral leg is observed for a rise off the mat; the angle of rise is indicative of the degree of hip flexor tightness present (Magee, 1992).
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CHAPTER 1
INTRODUCTION

Background to the Problem

As many as 85% of adults will experience low back pain at some time in their lives (Vakos, J., Nitz, A., Threlkeld, A., Shapiro, R., & Horn, T., 1994). In 1988, spine related pathologies accounted for 51.7% of the 29.9 million musculoskeletal impairments. Of these pathologies, 81% involved the low back (Frymoyer, 1996). The high incidence of low back pain in the working population is not only a health concern, but also an economical matter. The total cost of low back disorders has been estimated to be between $20 to $50 billion annually in the United States (Phillips, J., Forrester, B., & Brown, K., 1996). A new approach must be taken to reduce the incidence of low back pain and decrease the occurrence of disability. Since research has not recognized a proven treatment for low back pain, it would seem logical to prevent the condition. Previously it was believed that low back pain was relatively uncommon among school age children. Recent school-based surveys suggest otherwise. These surveys indicate a particularly high incidence of backache among children and teenagers, primarily in the low back (Salminen, J., Erikintalo, M., Laine, M., & Pentti, J., 1995). Some adolescents begin to experience low back pain at 13 to 14 years of age and the prevalence tends to increase with growth (Salminen et al., 1995). Low back pain in youth is often associated with poor sitting posture, sports activities, anthropometric factors, inactivity, and weak abdominals (Salminen, J., Maki, P., Oksanen, A., & Pentti, J., 1992; Fairbanks, J., Pynsent, P., Poorvliet, J., &
Phillips, H., 1984). It has also been suggested that low back pain in the adolescent period is positively associated with an increased frequency of low back pain in adults (Harreby, M., Neergaard, K., Hesselsoe, G., & Kjer, J., 1995).

The prevalence of low back pain in school age children supports the need for intervention at an early age. Previous studies have examined the success of early intervention in schoolchildren. One research study looked at the effectiveness of teaching school children proper lifting techniques to prevent low back pain (Sheldon, 1994). Children in schools are an appropriate population to target for intervention because postural habits and body mechanics are being impacted upon early in life (Nissinen, M., Helovaara, M., Seitsamo, J., Alaranta, H., & Poussa, M., 1994; Olsen, 1990). Sheldon's research supports prevention in childhood and provides evidence that back care education should begin early in development.

Due to decreasing fitness levels among school age children, the government is currently funding a number of programs to promote health in youth such as the Physical Best and Fitnessgram (President's Council on Youth Fitness, 1997). The purpose of fitness tests in schools is to promote good health habits in youth with the intent that the habits learned will carry over to adulthood. In turn, the adopted healthy lifestyle will contribute to decreasing the incidence of preventable impairments in adulthood. One of these programs, the Presidential Physical Fitness test battery, was originally established in 1966 by President Lyndon B. Johnson to encourage better fitness among adolescents (The President's Council on Youth Fitness and Sport, 1997). In order to compete with developing fitness programs, the test has been
revised on numerous occasions and is currently used nationwide. This fitness test is valid and is used as a basis for normative data on 6-17 year olds (The President’s Council on Youth Fitness and Sport, 1997).

The premise of the Presidential Physical Fitness Test seems appropriate but may unintentionally encourage poor biomechanical habits in participants. For example, the abdominal strength portion of the fitness test emphasizes performance rather than quality of movement. It is the quality of the exercise which serves to improve strength and endurance of the abdominals (Kendall, F., McCreary, E., & Provance, P., 1993). Fitness tests that emphasize performance may allow participants to obtain misleading high scores without having good abdominal strength.

The bent-knee sit-up used in the Presidential Physical Fitness Test may promote muscle imbalances between the flexors and extensors of the lower trunk. Authors agree that this muscle imbalance is a contributing factor in the development of an excessive lordotic posture (Kendall et al., 1993; Kisner & Colby, 1990). Lumbar lordosis has been associated with an increased incidence of low back pain, especially in women (Nissinen, et al., 1994; Salminen et al., 1992). The posture stretches and weakens the abdominals (rectus abdominis, external and internal obliques) while shortening the hip flexors and lumbar extensors (Kisner & Colby, 1990). This imbalance increases the stress to the low back, resulting in pain. Research analyzing the traditional bent-knee sit-up with the participant's feet held down indicate that emphasis is placed on increasing hip flexor and abdominal muscle imbalance (Vincent, W., & Britten, S., 1980; Robertson, L., & Magnusdottir, H., 1987). This position
contributes to an exaggerated anterior pelvic tilt and excessive lumbar lordosis which can be potentially harmful to the low back (Kendall et al., 1993).

Problem Statement

Children are subject to fitness testing at very early ages. The abdominal strength component of many fitness tests advocates performing a maximal number of bent-knee sit-ups in 60 seconds. Children are also encouraged to practice these sit-ups in order to improve future scores on abdominal tests. An excessive lordotic posture is often encouraged by performing the bent-knee sit-up. Lordotic posture has been linked to an increased prevalence of low back pain. Muscle imbalances also promote an exaggerated lordotic posture.

Purpose

Past research demonstrates deficiencies in the literature involving preventative measures in schoolchildren and the incidence of low back pain. Gaps also exist regarding current examination and validity of fitness testing. The purpose of this study is to examine a common component of most physical fitness tests, abdominal strength, and compare the results with tests used in the physical therapy profession. The results of abdominal strength will be correlated with low back posture.

The results of the study may encourage school systems, health professionals, parents, and children to address prevention and early intervention to control the development of musculoskeletal impairments of the lower back. The emphasis is to promote proper biomechanical exercise techniques to correct muscle imbalances occurring at the trunk. Decreasing muscle imbalances will provide a more optimal
lumbar posture, and ideally decrease future episodes of low back pain. The results of the study may show supporting evidence that physical therapists should take a preventative role in the "healthy" community.

**Significance of the Problem**

Although literature has proven that bent-knee sit-ups create harmful muscle imbalances between the trunk flexors and extensors, this fitness test is commonly utilized in school systems today. Physical educators, children, parents, insurance agencies, and practitioners need to be aware of the possible consequences of participating in certain forms of abdominal fitness testing and exercise.
CHAPTER 2
REVIEW OF LITERATURE

Introduction

There are a number of factors that contribute to low back pain. Prevention and early intervention appear to be the solution to this problem. Physical fitness testing has been performed in school systems nationwide since the 1950's. The Presidential Physical Fitness Award Program and the AAHPERD Physical Best were two fitness tests designed to promote a healthier lifestyle through exercise and fitness education. Abdominal strength testing is a part of present fitness test batteries. The literature review will focus on the following topics as they are related to abdominal strength testing and posture in school children:

1) low back pain in children and adults
2) normal postural alignment and its relationship to muscle imbalances,
3) physical fitness tests
4) intrinsic and extrinsic motivation factors and their association with fitness testing
5) anatomy of trunk musculature
6) abdominal muscle testing
7) instrumentation
8) prevention and intervention of low back pain
9) stabilization of the spine

Low Back Pain

Low back pain is the second most common reason, next to the common cold, that people seek medical attention and lose time from work (Frymoyer, 1996). The condition frequently affects the population in the most productive years, and accounts for the leading cause of disability of those 45 years old and younger (Phillips et al., 1996). One research study estimated that 80% of all low back pain is related to
muscle imbalances around the pelvis, trunk, hips, and faulty postures (Cram, & Steger, 1983). Other researchers have also supported this finding, stating that between 80-90% of backaches are due to improper posture, poor body mechanics, weak abdominal muscles, and decreased flexibility of the low back (Kazmaier, 1989).

In reviewing the literature regarding trunk muscle strength ratios in patients with low back pain, there exist many discrepancies. Beimborn and Morrissey (1988), found that trunk extension is about three times stronger than trunk flexion, yet other researchers believe the trunk flexors exert greater torque. Cantu (1982) suggested abdominal and hip flexor muscles can contribute to low back pain. He reported that hip extensor muscles are a primary contributor to controlling lumbar lordosis. Muscle development and strengthening begin at birth and continue to develop throughout elementary school with physical fitness tests and physical education courses. Physical education curriculums often use the sit-up as a tool to build abdominal strength and endurance. However, the literature reveals that this exercise promotes muscle imbalances that lead to postural abnormalities (Kendall et al., 1993; Sahrmann, S., 1983). Postural abnormalities, if not corrected, can lead to low back pain starting in children as early as 13-15 years old (Salminen et al., 1992; Fairbanks et al., 1984; Salminen et al., 1995). Boys with low back pain were found to have a more prominent kyphosis, while girls with low back pain had increased lumbar lordosis and pelvic tilt (Nissinen et al., 1994).

School-based surveys have proven back pain is increasing among children and adolescents (Salminen et al., 1995). Fairbanks et al. (1984), conducted a study which
demonstrated a high incidence of back pain in adolescents. The results indicated that children with low back pain displayed decreased lower extremity flexibility, avoided sports, and had increased weight and sitting trunk height. The data revealed that the onset of back pain occurs before the age of 15 years. In support of Fairbanks’ findings, Harreby et al. (1995), found that adolescents who experienced low back pain had an increased frequency of low back pain in adulthood. In conclusion, the increased prevalence of low back pain in adolescents and its positive relationship to the incidence of back pain in adulthood, demonstrate the need for prevention and intervention at an early age.

Posture and Muscle Imbalances

Nationwide, physical therapy curricula reference Kendall’s textbook, *Muscles: Testing and Function; 4th ed.* (1993), regarding muscles and their role in posture and function. Kendall believed that the definition of posture proposed by the Posture Committee of the American Academy of Orthopaedic Surgeons in 1947 was so comprehensive and well stated that she chose to utilize it in her discussion of posture and pain. The definition reads as follows:

Posture is usually defined as the relative arrangement of the parts of the body. Good posture is that state of muscular and skeletal balance which protects the supporting structures of the body against injury or progressive deformity irrespective of the attitude (erect, lying, squatting, stooping) in which these structures are working or resting. Under such conditions the muscles will function most efficiently and the optimum positions are afforded for the thoracic and abdominal organs. Poor posture is a faulty relationship of the various parts of the body which produces increase strain on the supporting structures and in which there is less efficient balance of the body over its base of support (Kendall et al., 1993, p. 4).
Traditionally, Kendall uses a plumb line test to assess ideal lumbar alignment. According to Kendall, the plumb line must pass through the bodies of the lumbar vertebrae, run slightly posterior to the axis of the hip joint, and through the sacral promontory reference points (Kendall et al., 1993). Any differences observed from the plumb line during the assessment are noted as deviations from normal. Normal postural development in adolescents involves varying rates of growth. At this stage in development, body types become fixed. For this reason, postural deviations are important to future postural alignment. The lumbosacral angle is critical in lumbar posture. In the pre-adolescent period, a protruding abdomen and increased lumbar lordosis is not abnormal and should not be seen as a postural defect (President's Council on Physical Fitness and Sports, 1979). Ideally the lumbosacral angle should be approximately 30° from the horizontal to be considered part of a normal lumbar lordosis (Kisner & Colby, 1990). Tilting the sacrum anteriorly increases this angle and results in increased shear forces at the lumbosacral joint and an increase in the anterior lumbar convexity, possibly leading to pain and discomfort in the lumbar region (Kisner & Colby, 1990).

Poor posture, if not corrected, can lead to postural pain syndrome or postural dysfunction. Postural pain syndrome is described as a postural fault that deviates from normal alignment but has no structural limitations (Kisner & Colby, 1990). Unlike postural syndrome, postural dysfunction involves structural limitations possibly caused by prolonged poor postural habits. Adaptive shortening and muscle weakness are the result of postural dysfunction. Stress to the shortened structures and overuse of the
weakened, stretched structures cause pain and disability if therapeutic intervention is not implemented (Kisner & Colby, 1990). Kuhns (1949) reported that minor faults in postural alignment will contribute to pain and disability in the future. He emphasized that with minor deviations, symptoms may take years to develop. This opinion supports the idea that postural screening and early intervention should be performed on schoolchildren.

The topic of muscle imbalance has been described by numerous authors (Kendall et al., 1993; Janda & Schmid, 1980; Sahrmann et al., 1987; Richardson & Jull, 1995). Postural muscles such as the iliopsoas, erector spinae, tensor fascia latae, and the rectus femoris tend to tighten when a muscle imbalance exists, creating an anterior pelvic tilt (Jull & Janda, 1987; Kendall et al., 1993; Kisner & Colby, 1990). It should be noted that these muscles may also lengthen with certain postural deformities. Tight muscles are activated earlier in movement patterns and need to be critically assessed during strength testing. A muscle may appear to be strong secondary to the fact that it has been shortened (Norris, 1995). The rectus abdominis and internal and external obliques are phasic muscles which become lengthened and weak with an excessive lordotic posture (Jull & Janda, 1987; Kendall et al., 1993; Kisner & Colby, 1990). Kendall proposes that these muscles undergo a stretch-weakness which pertains to the muscles remaining in an elongated condition beyond their neutral resting position, but not beyond their normal muscle length (Kendall et al., 1993). The condition results from prolonged, habitual postures, inactivity, and injury (Kisner & Colby, 1990; Kendall et al., 1993). Muscle imbalances tend to occur in specific
patterns, particularly around the pelvis and the shoulder. The pelvic crossed syndrome refers to the imbalance of shortened hip flexors and erector spinae, and weak and lengthened abdominals and gluteal muscles. This syndrome leads to an increased anterior pelvic tilt (Janda & Schmid, 1980).

Muscle imbalances may lead to a variety of postural deformities and mechanical strain. Increasing muscle length of the abdominals has been proven to be positively correlated with lumbar lordosis (Nachemson & Lindh, 1965). Lumbar lordosis is characterized by an increased lumbosacral angle, shortening of the hip flexors and erector spinae, and lengthening of the abdominals. This posture contributes to increased anterior lumbar convexity and increased anterior pelvic tilt when compared with ideal postural alignment (Kendall et al., 1993; Kisner & Colby, 1990).

Postural deviations in childhood such as scoliosis, growth asymmetries, and nutritional factors, influence the normal development of the musculoskeletal system. Activities which involve the emphasis of certain muscle groups may create muscle imbalances early in development. Environmental conditions such as desk and seat height, as well as mattress firmness may also add to postural faults (Kendall et al., 1993). Research has also indicated that arthropometric factors contribute to postural pain. Sitting and standing heights, as well as the weight of a child were positively correlated with the development of postural pain syndromes (Nissinen et al., 1994; Fairbanks et al., 1984). Nissinen et al., (1994); and Fairbanks et al., (1984) found
children with increased trunk height in both sitting and standing had an increased
tendency to experience low back pain.

**Fitness Tests**

In 1954, Kraus and Hirschland compared the fitness of European and
American youth (Corbin & Pangrazi, 1992). The results revealed that nearly 60% of
American youth failed at least one portion of the test battery for fitness in comparison
to only 10% of European children (Corbin, C., Prong, T., & Rutherford, W., 1992).

In response to this study, President Eisenhower formed the President’s Council on
Youth Fitness to promote physical fitness nationwide (Corbin et al., 1992). Members
of this council formed a special committee called the American Alliance for Health,
Physical Education, Recreation and Dance Research Council which developed a
comprehensive set of fitness tests and surveys inquiring about youth fitness nationwide
(Plowman, 1992).

In 1966, President Lyndon B. Johnson established the Presidential Physical
Fitness Award Program. This program had 3 main objectives: 1) to produce physically
fit youth, 2) to educate young people concerning the essential nature of physical
activity and its relationship to health, physical fitness, and a dynamic, productive life,
and 3) to give students the skills, knowledge and motivation to remain fit (President’s
Council on Physical Fitness and Sport, 1997). The Council suggests the test should be
administered twice a year to 6-17 year old school children. The current components
of the Presidential Physical Fitness Award Program include: the one mile run/walk, sit
and reach, curl-ups, shuttle run, and pull-ups. Students must perform in the 85th
percentile or higher when compared to normative data, in order to receive the
Presidential Physical Fitness award. In 1988 an additional award, the Presidential
Physical Fitness Certificate, was developed for children performing in the 50th to 85th
percentile in the test batteries. Normative data are collected every decade and are
compared to previous decades data to establish fitness performance patterns in school
children.

Currently, there are six test batteries for evaluating youth fitness. The
following programs are utilized in school systems: AAHPERD Physical Best,
Chrysler-AAU Fitness Test, Fit Youth Today, FITNESSGRAM, Presidential Physical
Fitness Award Test, and the YMCA Youth Fitness Test (Plowman, 1992). Each test
assesses cardiorespiratory endurance, lower back flexibility, abdominal
strength/endurance, and upper body muscle strength/endurance. Other fitness tests
incorporate body composition and power and agility of the lower extremities
(Campbell, 1995). Physical fitness tests have been scrutinized in the past few decades
for their lack of validity and reliability. Most tests have been proven to have inter-
rater reliability, however; little is known regarding their validity (Campbell, 1995).

Kendall et al. believes that the bent-knee sit-up test should be re-evaluated due
to misleading results and adverse effects on children (1993). She states:
The usefulness of these tests depends on their accuracy and on their ability to
detect deficiencies. Unfortunately, these tests have become an evaluation of
the performance rather than a measure of physical fitness of the performer. Emphasis is on excesses-speed of performance, number of repetitions, and
extent of stretching-rather than on quality and specificity of movement
(Kendall et al., 1993, p. 7)
Extrinsic and Intrinsic Motivation

Many fitness tests are based on the use of an award system that acknowledges only exemplary performance from participants. When employing an award system with fitness testing, intrinsic and extrinsic motivation factors must be considered when evaluating results. Graham and Hopple (1995) examined the thoughts and feelings of 4th and 5th grade students on the 1 mile run/walk. Results revealed the students did not have a clear understanding of what the fitness test entailed. Most students also considered high pressure to perform as a negative aspect of the test. The research suggested that the children were not actually being “physically educated”. It also suggested that children who have negative experiences with fitness may cease to participate in fitness activities as an adult (Graham and Hopple, 1995).

Fitness tests should support the fitness habits of all participants to allow for a more positive experience at all levels of performance. Interpreting tests through percentile-based scores may decrease intrinsic motivation among those who perform poorly on fitness tests (Corbin & Whitehead, 1991; Corbin, et al., 1992). Positive reinforcement will encourage more children to carry on a healthy lifestyle that includes fitness into adulthood. Results of a study by Corbin et al. (1992) indicated that positive feedback following a fitness test resulted in increased competence and reduced anxiety associated with participation. Fitness tests may need to encourage exercising correctly and focus on the process of the skill, rather than the result (Corbin et al., 1991; Harter, 1980). It should be noted that the Fit Youth Today, FITNESSGRAM, and Physical Best test batteries base testing procedures on proper
exercise techniques (Corbin & Whitehead, 1991). In regard to current literature on motivational factors, fitness tests that encourage reward systems should focus on participation and quality of the skill tested, rather than percentiles and product-focused awards.

Components of the Trunk

Normal functioning of the spine is controlled by muscles, which serve as the stabilizing system for the lumbar spine (Norris, 1995). In reference to lumbar stabilization, the following muscles are considered to be primary in trunk control: rectus abdominis, internal and external obliques, hip flexors (iliopsoas), erector spinae, and transversus abdominis. The primary action of the rectus abdominis is to flex the vertebral column by approximating the thorax and pelvis anteriorly (Kendall et al., 1993). This muscle originates at the pubic crest and pubic symphysis and inserts at the costal cartilages of the 5th through 7th ribs, and xiphoid process of the sternum (Kendall et al., 1993). When this muscle weakens, it becomes more difficult to flex the vertebral column, and perform a posterior pelvic tilt from the supine position (Kendall et al., 1993). The rectus abdominis muscle is often found stretched and weakened in individuals with a lordotic posture (Norris, 1995). The internal and external oblique muscles act to compress and support the abdominal viscera and flex and rotate the trunk. The lateral fibers of the external oblique muscle act indirectly on the lumbar spine via a posterior tilting of the pelvis (Moore, 1992; Kendall et al., 1993). The transversus abdominis muscle does not act as a trunk stabilizer alone. It assists the anterior abdominal muscles in flexing the trunk by compressing the
abdominal viscera and stabilizing the linea alba (Kendall et al., 1993). The erector spinae extend the vertebral column and control flexion moments of the trunk. The muscles commonly originate through a broad tendon attached to the iliac crest, sacrum, sacroiliac ligaments, and the sacral and lumbar spinous processes (Moore, 1992). These muscles are commonly involved in back strain when excessive flexion or rotation occurs (Moore, 1992). Because of the hip flexor (iliopsoas) attachment to the lumbar vertebrae, the muscles are considered important to lumbar stabilization. With the insertion fixed, a bilateral iliopsoas contraction acts to flex the hip by flexing the trunk on the femur as demonstrated in the sit up from supine position. The iliopsoas inserts on the lesser trochanter of the femur and the tendon of psoas major. It originates on the transverse processes and intervertebral discs of T-12 to L-5, the iliac crest and fossa, the sacrum, and the anterior sacroiliac ligaments (Moore, 1992; Kendall et al., 1993). A shortened iliopsoas results in an increased lumbar lordosis with an anterior pelvic tilt (Norris, 1995).

Stabilization of the Spine

It is well known that the lumbar dorsal fascia and intra-abdominal pressure stabilize the spine. Research shows that spinal stabilization is best achieved by facilitating a co-contraction of the obliques, transverse abdominus, erector spinae, and the multifidi (Richardson, C., Toppenberg, R., & Jull, G., 1990). The literature has implied that the rectus abdominus may inhibit these spinal stabilizers (Richardson & Jull, 1995). Therefore, training of the rectus abdominus is not as important as once believed. Dysfunction of the deep muscles of the spine such as the multifidi has been
found to differentiate patients with and without low back pain (Richardson et al., 1990). The transverse abdominus, multifidi, and internal obliques maintain spinal stability segmentally (Richardson & Jull, 1995). The transverse abdominus contracts in all directions of trunk movement and is recruited earlier than the other abdominal muscles (Cresswell, A., Grundstrom, A., & Thorstensson, A., 1992). Co-contraction of the multifidi and lateral abdominal muscle groups is optimal for lumbar stabilization (Shields & Heiss, 1997).

The sit-up exercise emphasizes the upper rectus abdominus (Lehmkuhl & Smith, 1983). The double leg lowering test demonstrates greater electromyographic (EMG) muscle activity in the external and internal oblique muscles when compared with the sit-up exercise (Shields & Heiss, 1997). The curl-up and bent-knee sit-ups are overemphasized exercises in rehabilitation. Exercises involving rotation, activation of the lateral abdominal groups and decreased rectus abdominus activity would prove most beneficial to lumbar stabilization. (Shields & Heiss, 1997).

Abdominal Strength Tests

The bent-knee sit-up has been used to strengthen abdominals in schoolchildren and military personnel. This exercise has been under great scrutiny for it’s lack of specificity and potentially harmful effects to the lower back. Researchers have discovered the bent-knee sit-up places a high demand on the hip flexor muscles and less demand on the abdominal muscles (Robertson & Magnusdottir, 1987). The abdominal muscles account for the first 20° to 30° of the sit-up. The remaining range of motion for this exercise is completed by the hip flexors (Vincent & Britten, 1980).
Many educational programs advocate practicing the bent-knee sit-up to improve scores on fitness tests (Vincent & Britten, 1980; The President’s Council on Physical Fitness and Sports, 1987). This practice may result in muscle imbalance between the hip flexors and abdominals, leading to an exaggerated anterior pelvic tilt. The bent-knee sit-up test requires the participant’s feet to be stabilized by a partner. This position can be potentially harmful to the low back because of the overactive influence of the hip flexors on the lumbar spine (Robertson & Magnusdottir, 1987). Kendall et al. (1993) states that holding the feet down during a sit-up, stabilizes the center of gravity, and promotes early activation of the hip flexors. With the feet stabilized, the subject tends to assume an arched back position. Holding the feet may not effect strength grading with a few repetitions, but as the number of consecutive sit-ups increase, test results can not accurately assess endurance.

The trunk curl phase is essential to evaluating abdominal strength. This phase must preceed the hip flexion phase to avoid an undesired anterior pelvic tilt (Kendall et al., 1993). A posterior pelvic tilt was found to be critical for optimal abdominal activity during the sit-up (Shirado, O., Kaneda, K., & Stax, T., 1995). Many times a posterior pelvic tilt can not be maintained while performing the bent-knee sit-up because of active hip flexors and their tendency to hyperextend the lower back during the movement (Vincent & Britten, 1980). Isokinetic testing revealed little connection between isokinetic abdominal strength results and timed sit-up tests. This may indicate that timed sit-up tests do not adequately isolate the abdominal muscles and are not useful tools in assessment (Hall, G., Hetzler, R., Perrin, D., & Weltman, A., 1992).
Kendall et al. (1993) criticizes the bent-knee sit-up test claiming it is not a true measure of strength and endurance of the abdominal muscles, but instead emphasizes the hip flexor muscles. Kendall believes the position of the trunk is critical to isolating the abdominal muscles during testing. In schools, most fitness tests fail to differentiate between the "curled-trunk sit-up" and the "arched-back sit-up". The first sit-up focuses on utilizing the abdominals to flex the trunk and hold the position throughout movement. Although this is the proven method to isolate the abdominals, many students use the "arched-back sit-up", which stretches the abdominals and strains the low back. The "arched-back sit-up" is resorted to during testing because students lack sufficient abdominal endurance to maintain a curled trunk for 60 seconds (Kendall et al., 1993). Students tend to compensate for weak abdominals by arching the back and using the hip flexors, allowing for a large margin of error in scoring the test. Kendall (1993) states, "those with weak abdominal muscles can pass this so-called "abdominal muscle test" with a high score (p. 7). Repetitions should only be counted if the trunk is held in flexion throughout the curl-up. When testing abdominal strength and endurance, the focus should be on maintaining the trunk curl throughout the range of motion, instead of the speed of the performance (Kendall et al., 1993).

A standard method to assess upper abdominal strength in physical therapy is Kendall's Upper Abdominal Strength test. When testing the upper abdominals, Kendall et al. (1993) positions the subject supine with the lower extremities extended and the hands clasped behind the head. The position eliminates the assistance of the hip flexors in curling the trunk. As mentioned above, Kendall et al. (1993)
recommends only holding the feet, if needed, after trunk flexion has been completed and hip flexion has been initiated. Kendall’s Upper Abdominal Strength test is graded according to the subject’s arm position while completing the test. Corresponding grades and test positions can be found in Appendix A.

Kendall also proposes a method for assessing lower abdominal strength. The Lower Abdominal Strength test cannot be accurately used to assess children under the age of eight. It is difficult for young children to understand and achieve a posterior pelvic tilt, which is a necessary component of the test (Kendall et al., 1993). The weight of the legs in small children is an important factor. Since the weight of the legs approximates the weight of the trunk, most children can easily lower and raise the legs without arching the back, regardless of lower abdominal strength (Kendall et al., 1993). In early adolescence, the legs grow longer in relation to the trunk and sufficient torque is exerted on the lumbar spine and pelvis during leg lowering via the Iliopsoas. The test is administered by positioning the subject supine with both legs at approximately 90° with knees extended. A strength grade is obtained at the angle when the pelvis begins to tilt anteriorly during active leg lowering. Abdominal muscles are graded according to a scale that runs 90° to 0°, corresponding with the pelvic tilt. Grading criteria and positions of the test may be obtained from Appendix B.

**Measuring Tools**

Several instruments for measuring lumbar lordosis have been cited in the literature. It is important clinically to have valid and reliable tools to quantify the
degree of lumbar lordosis. Accurate measurements contribute to effectiveness of
treatment in the clinic. Tools such as skin markers, pendulum goniometers,
photography with external markers, flexible rulers, hydrogoniometers, radiographs,
and hand-held stylus' with multturn potentiometers are used to assess lumbar lordosis
(Hart, 1986; Burton, 1986). The flexible ruler, also referred to as the flexicurve, has
been proven to be reliable and valid (Hart, 1986; Lovell, 1989). One study claims that
intra-tester reliability is more dependable than inter-tester reliability (Burton, 1986).
Burton found an intra-reliability correlation coefficient of 0.97 and an inter-reliability
correlation coefficient of 0.88 when measuring the curve of the low back with the
flexicurve (1986). Researchers suggest using one tester to perform measurements on
subjects to improve accuracy of testing (Lovell, 1989). The validity of the flexicurve
has been positively compared to radiographs and hydrogoniometers (Burton, 1986;
Hart, 1986). Results demonstrate the flexicurve to be a good non-invasive measure of
lumbar lordosis. The tool is also inexpensive, easy to use, and efficient in clinical and
research environments (Burton, 1986).

Lumbar stabilization is an integral part of low back education. A posterior
pelvic tilt is often difficult for patients to perform and maintain. Biofeedback has been
proven to assist patients with proprioception and kinesthetic awareness (Miller &
Medeiros, 1987). In a study conducted by Norris (1995), the Stabilizer Pressure
Biofeedback unit (Chattanooga Group Limited, Bicester, UK) was used to monitor a
posterior pelvic tilt during lumbar stabilization exercises. The biofeedback unit
assisted the researchers in obtaining objective results regarding trunk stabilization.
Kendall's lower abdominal strength measurement chart will be used to assess lower abdominal strength (Kendall et al., 1993). The chart was devised utilizing a goniometer for degree measurements (See Appendix B).

Prevention and Intervention

Low back pain is a common medical diagnosis often treated with extensive rehabilitation. Although this topic has been researched thoroughly, no proven cure or treatment protocol has been established. Current researchers have found little difference between conservative treatments for low back pain (Waddell, 1987). Lordotic posture has been associated with increased episodes of low back pain. Toppenberg and Bullock (1986) suggest shortening of the abdominal muscles will decrease the degree of lumbar lordosis, thereby eliminating stress which creates pain on the posterior aspect of the spine. The trunk musculature is critical to lumbar posture and stabilization. When muscles become stretched or shortened, abnormal forces are exerted on the lumbar spine creating excessive flexion and extension. If the forces are large enough, they can produce faulty alignment which may lead to pain. In a lordotic posture, the abdominal musculature is typically stretched and weakened while the hip flexors and back extensors are often shortened and strong (Kisner & Colby, 1990). One author reported, “Exercise and education are the only two tools that have been proven successful for prevention and conservative treatment” (White, 1989, p.295) Considering the success of current low back pain treatment, the best course of action may be prevention and early intervention. Educating the population about proper posture, lifting techniques, ergonomics in the working environment, and
the effects of muscle imbalances may decrease the incidence of low back pain. Abdominal strengthening has also been advocated to reduce muscle imbalances and improve posture.

Lumbar stabilization exercises are often employed as protective mechanisms for the back. Kendall et al. (1993) recommends a curl-up to strengthen the upper abdominals. This exercise needs to be performed in a slow, controlled manner emphasizing flexion of the trunk for optimal results. A leg-lowering exercise incorporating a posterior pelvic tilt is suggested to strengthen the lower abdominals. The lower abdominals are key muscles in prevention of the development of an excessive anterior pelvic tilt (Norris, 1995).

A study performed with schoolchildren demonstrated the effectiveness of early intervention. Sheldon (1994) implemented an instructional program teaching students proper lifting techniques. Six to seven weeks after completion of the teaching sessions, results indicated good retention of the new lifting skills attained during the first teaching session. The study supports the introduction of early preventative measures during childhood. These measures would have a positive effect on adolescent lifting techniques and spinal alignment. Sheldon (1994) believes childhood is the best time to influence postural habits and body mechanics because this stage of life is the period when these areas undergo considerable development. It can be concluded, from these studies that a logical time for back education would be in childhood.
Physical therapists do not currently play a major role in prevention of musculoskeletal impairments in healthy individuals. Physical therapists typically intervene when patients have a disability, impairment, or injury. Sahrmann (1993) strongly believes physical therapists are best prepared academically to recognize, evaluate, and treat musculoskeletal dysfunction in the normal individual. Physical therapists possess the expertise to serve as advisors in the development of physical fitness programs. Currently, physical therapists do not serve on the President’s Council for Physical Fitness and Sports (1996). This Council devises and recommends exercise programs and fitness tests used to determine the level of fitness in schoolchildren today. Physical therapists can positively contribute to the health and well being of schoolchildren nationwide by sharing the expertise and skills of the profession.

Conclusion

The literature has proven the need for preventative measures in correcting postural deviations that could lead to dysfunction. The literature review investigates the common components most critical to successful abdominal strength and postural assessment in children. Since the correlation has been drawn between abdominal fitness testing and its potential adverse effects on posture in schoolchildren, more research on this topic seems appropriate. Current literature reveals a shortage of pertinent information on the topic.
Hypotheses

1. Male and female students categorized as “Fit” on the Presidential Physical Fitness Abdominal Test will demonstrate a statistically significant association to students categorized with “Weak” lower abdominal muscle strength on the Kendall Lower Abdominal Muscle Test ($\alpha \leq 0.05$).

2. Male and female students categorized as “Fit” on the Presidential Physical Fitness Abdominal Test will demonstrate a statistically significant association to students categorized with “Strong” upper abdominal muscle strength on the Kendall Upper Abdominal Muscle Test ($\alpha \leq 0.05$).

3. Male and female students categorized as “Fit” on the Presidential Physical Fitness Abdominal Test will demonstrate a statistically significant association to students categorized with “Above Normal” lordotic posture ($\alpha \leq 0.05$).

4. Students categorized with “Weak” lower abdominal strength scores on the Kendall Lower Abdominal Test will demonstrate a statistically significant association to students categorize with “Above Normal” lordotic posture ($\alpha \leq 0.05$).
CHAPTER 3
METHODOLOGY

Study Site and Subjects

Data collection was performed at local elementary schools in Grand Rapids, Michigan. A practice session included subjects from the Focus on Ability camp conducted during the summer at Grand Valley State University. Approval was obtained from the coordinators, counselors, teachers, and principals of all the participating facilities. A research proposal was approved by the Human Subject’s Review Board (See Appendix C).

The subjects consisted of 58 female and 5 male local 5th/6th graders, ages 10-11 years old. All participants were required to meet the inclusion criteria through the prescreen testing.

Inclusion criteria:

1. The subjects must be 10-11 years old
2. The subjects must demonstrate ability to achieve a posterior pelvic tilt
3. The subjects must be in good general health
4. The subjects must have no more than a 20° restriction of knee extension when performing the 90/90 straight leg raise test
5. The subjects must be able to follow basic directions required to achieve objectives of the study
6. The subjects must have no history of low back pain within the last year
7. The subjects must have no present spinal pathologies
8. The subjects must have no history of lower extremity pathologies
9. The subjects must have no history of abdominal or lower extremity surgery within the last 2 years
Children from the testing sites came from a number of different school districts and backgrounds. Although data was not collected on the ethnicity of the subjects, the majority of the subjects from the first test site were Caucasian, whereas the second site was mostly African American. All students followed identical test protocols, performed in a random order.

**Design**

The study demonstrated a relationship between abdominal muscle strength in children to lordotic posture. The study consisted of a prescreen, three abdominal muscle tests, and a postural assessment. The design included a description of the independent and dependent variables, the randomization procedure, and the instrumentation used.

Independent and Dependent Variables

Independent Variables:

1) Kendall's Upper Abdominal Muscle Strength results
2) Kendall's Lower Abdominal Muscle Strength results
3) Presidential Physical Fitness Abdominal Strength Test results

Dependent Variable:

1) degree of lumbar lordosis

**Instruments**

The Stabilizer Pressure Biofeedback Unit was used to monitor the maintenance of the posterior pelvic tilt position while performing the Kendall Lower Abdominal Strength Test. The Stabilizer utilizes biofeedback to assist the participant in flattening the lower back. The unit consists of a rubber bladder and a pressure gauge similar to a
sphygmomanometer (See Appendix D). The device was placed under the lower back and the subject was asked to perform a posterior pelvic tilt. Before the Kendall Lower Abdominal Test, subjects performed a posterior pelvic tilt. At this time, the pressure gauge was set at 40 mmHg of pressure. This is the recommended amount of pressure that should be used according to the Chattanooga Company (Chattanooga, 1995). The gauge was monitored during the lower abdominal test for a 5-8 mmHg decrease in pressure indicating the inability to maintain a posterior pelvic tilt.

Kendall’s chart for lower abdominal strength testing was used to measure the angle of the lower extremities in Kendall’s Lower Abdominal Test (See Appendix B). The chart taken from the book *Muscles: Testing and Function* was duplicated for the use of this study (Kendall et al., 1993). The chart was constructed using a goniometer and straight edge ruler.

The Flexicurve was utilized to measure lumbar lordosis. The ruler is 61 cm long, 0.8 cm wide, and is made of a pliable metal band enclosed in plastic (See Appendix E).

Reliability and Validity

A current research study used the Stabilizer Pressure Biofeedback Unit to assist participants with achieving a posterior pelvic tilt (Norris, 1995; Richardson & Jull, 1995). Miller and Medeiros have suggested that multisensory feedback similar to the instrument used in this study is effective in assisting with abdominal stabilization exercises (1987). Reliability has been established for the Flexicurve in measuring lumbar lordosis. Researchers have proven in a study conducted in 1986 1989 that the
correlation coefficient for intra-reliability was found to be 0.97 which demonstrates good to excellent reliability (Burton, 1986; Portney & Watkins, 1993). Other researchers have found the flexicurve to be a reliable noninvasive tool for measuring the degree of lumbar lordosis in the low back (Hart, 1986; Lovell, 1989).

**Randomization Procedure**

The study was conducted by collecting a subject sample of convenience. The abdominal strength testing was randomized by having subjects select the order of abdominal test administration by drawing random index cards labeled with each of the three tests.

**Procedures**

Permission was granted from the coordinators, counselors, teachers, and principals at participating facilities. Informed consent and a prescreen questionnaire were obtained from the parent/guardian and participants of the study as specified by the Human Subjects Review Board at Grand Valley State University (See Appendix F).

The research study began with an informal information discussion between each subject and the researchers (See Appendix G). The session provided details of the testing procedure and gave the subjects an opportunity to ask questions. At this time the subjects were given the opportunity to withdraw from the study. Data was recorded on an individual sheet for each subject (See Appendix H). A prescreen was administered to each subject by the testers. After meeting inclusion criteria, the students underwent a pre-testing postural assessment of the lower back using the
Flexicurve. The students then drew the order the abdominal tests were performed by drawing randomly from index cards. Abdominal strength was tested using Kendall’s Upper Abdominal Strength Test (See Appendix A), Kendall’s Lower Abdominal Strength Test (See Appendix B), and the Presidential Physical Fitness Abdominal Test (See Appendix I). Following each abdominal test a 5 minute rest period was given to each participant. Following the abdominal tests, a post-postural assessment with the flexicurve was performed. Participants in the study were thanked for their participation. At that time, subjects were given the opportunity to ask any additional questions. Students were dismissed from the study and given a piece of candy which served as a token of appreciation.

Prescreen

An informed consent form and a prescreen questionnaire was sent home with the students for the parents to review, fill out and sign before any testing began (Appendix F). A prescreen consisting of three flexibility tests was administered to the subjects to insure the inclusion criteria were met before the study continued. The prescreen was performed in the same area where the abdominal tests were administered. The prescreen consisted of the 90/90 straight leg raise test, Thomas test, and demonstration of the ability to achieve a posterior pelvic tilt (Magee, 1992). Subjects were asked to lie supine on a mat in the hooklying position. A posterior pelvic tilt was demonstrated and instructed by the testers. Each student practiced and was assisted in achieving the position until the student was able to perform the maneuver independently without physical cueing. After mastering the posterior pelvic
tilt, participants' hamstring length was examined using the 90-90 straight leg raising test. The students were asked to remain supine on the mat and instructed to flex their hips to 90 degrees while the knees remained bent. The students then grasped behind their knees with their hands, stabilizing the 90 degree position. The students then slowly extended each lower extremity until maximum range of motion was achieved. The testers observed the angle of knee extension. If subjects were greater than 20 degrees from full extension, they were excluded from the study. The students were then tested for tight hip flexors using the Thomas Test. In the supine position on the floor, subjects were positioned with the lower extremities straight out in front of them. Subjects were asked to bring one knee to the chest and hold it, stabilizing with the upper extremities. The testers observed the degree of flexion which occurred at the hip in the extended lower extremity. If the extended lower extremity raised off the floor, where the posterior aspect of the thigh is no longer in contact with the floor, tight hip flexors were noted but subjects were included in the study. If students had any difficulty following simple instructions throughout the prescreen, they were excluded from the study.

Abdominal Muscle Tests

Kendall's Upper and Lower Abdominal Tests were used in this study to measure abdominal strength. The Presidential Physical Fitness Abdominal Test was also used to assess abdominal strength.

Kendall's Upper Abdominal Test began with the subjects supine and the legs extended. The subject performed a trunk curl slowly with the hands behind the head,
while attempting to reach a full sitting position with the spine in flexion. If subjects were unable to achieve a normal grade, the arm positions were modified according to the grading system (See Appendix A).

Kendall’s Lower Abdominal Test began with subjects supine with the arms folded across the chest. The tester assisted the patient in raising the lower extremities to a vertical position with the knees straight. The subjects performed a posterior pelvic tilt and held this position while slowly lowering the legs. The point at which the subject began to anteriorly tilt the pelvis, as monitored by the Stabilizer Pressure Biofeedback Unit, was noted and the angle measured from 90 degrees. The degrees measured were then compared to Kendall’s scale to obtain a strength grade. Values given on the Kendall chart were reassigned strength values from 1(normal)-6(fair) for convenience of data collection. (See Appendix B).

The Presidential Physical Fitness Abdominal Test began with the subjects in the hooklying position, with the heels no greater than 12 inches from the buttocks. The subject positioned their arms across the chest with their back flat on the floor. The tester set a stop watch for 60 seconds and instructed the student to raise the trunk high enough so the elbows touched the thighs and returned so the scapulas touch the floor. The subject was instructed to perform as many sit-ups in 60 seconds at the signal “go” and the test was terminated with the word “stop”. The fitness test was conducted under the following rules:

1. “Bouncing” off the floor/mat was not allowed.
2. The sit-up was counted only if the student 
   a. kept fingers touching shoulders 
   b. touched elbows to thighs
c. returned to position with scapula touching floor before sitting up again

3. No verbal cueing, except to correct body mechanics and positioning, was given.

Scores on the fitness abdominal test were matched with normative data for 10-11 year olds in the 50th percentile of the Presidential Physical Fitness Abdominal Tests (See Appendix I).

Posture

The Flexicurve was used to measure the degree of lumbar lordosis. The subjects were asked to stand in a relaxed position with their weight distributed equally with the feet shoulder width apart. The arms were relaxed at their sides and their heads were facing forward. One of the testers palpated the L1 and S2 spinous processes and marked them accordingly. S2 was located by palpati ng the PSIS and moving medially toward the adjacent spinous process. L1 was located by palpating the iliac crests and moving medially to find the L4/L5 interspace. The researcher proceeded to count up four spinous processes to locate L1. The other tester placed the Flexicurve over the spinous processes of the low back and molded it to fit the contour of the back. The curve was traced onto paper and points L1 and S2 were respectively labeled A and B. The line connecting A and B was labeled L, while H was the line perpendicular to the midpoint of L. The lines were measured to the nearest centimeter. The angle ($\theta$) was determined by the following equation: $\theta = 4 \times (\arctan(2H/L))$ (See Appendix J). For the purposes of this study, normal lumbar lordosis measurements were based on previous research on the Cobb method as described by Chernukha, K., Daffner, R., & Reigal, D. (1998).
**Statistical Analysis**

A Chi-square was used to determine the relationship between the subjects’ fitness level to their lower abdominal strength, fitness level to lordotic posture, and lower abdominal strength to lordotic posture (Portney & Watkins, 1993). Test re-test reliability was performed on the pilot study results to determine the reliability of the abdominal strength tests.

**Anticipated Problems and Solutions**

The following problems were anticipated:

1. **PROBLEM:** inability to detect when student loses posterior pelvic tilt with leg lowering test  
   **SOLUTION:** the Stabilizer Pressure Biofeedback Unit

2. **PROBLEM:** extrinsic motivation and feedback effecting test scores  
   **SOLUTION:** no verbal cueing will be given during abdominal tests except for instruction and correction of position

3. **PROBLEM:** obtaining subjects with similar backgrounds (i.e. social, economical, extra-curricular activities, etc.)  
   **SOLUTION:** testing will be performed in more than one type of school system

4. **PROBLEM:** inability to recognize excessive lumbar lordosis  
   **SOLUTION:** the Flexicurve will be used to measure lumbar curvature

5. **PROBLEM:** error occurring during goniometric measurements while determining the angle during the lower abdominal strength test  
   **SOLUTION:** use of the inclinometer for measuring the angle of the lower
extremities during the lower abdominal strength test

6. **PROBLEM:** participants in the study with low back pain, spinal and lower extremity pathologies  
   **SOLUTION:** a general history of the students will be taken before testing begins

7. **PROBLEM:** muscle fatigue affecting the abdominal test results  
   **SOLUTION:** subjects will be given a 5 minute rest period between tests

8. **PROBLEM:** subjects holding their breath (performing a Valsalva maneuver) during abdominal tests  
   **SOLUTION:** subjects will be instructed to count out loud if this is a perceived problem

9. **PROBLEM:** subject anxiety prior to testing  
   **SOLUTION:** procedures will be thoroughly explained and subjects will be given an opportunity to withdraw from the study

10. **PROBLEM:** ability to perform consistent, reliable data collection  
    **SOLUTION:** measuring techniques will be practiced and a pilot study will be conducted

11. **PROBLEM:** injury to the low back while performing Kendall’s Lower Abdominal Strength Test  
    **SOLUTION:** subjects will be asked to terminate the test immediately following the point the lower back arched off the surface
CHAPTER 4
RESULTS

Descriptive Data

Data was obtained from 63 subjects in two school districts. Northern Trails Elementary School provided 41 subjects from a suburban population of students in Grand Rapids, MI. Data was collected from 22 subjects from the Campus School of Art and Literature in the inner city of Grand Rapids, MI. Female subjects composed 92.1% (58) of the sample while 7.9% (5) of the sample was represented by males. Of the 63 subjects tested, 54.0% (34) were 10 year olds and 46.0% (29) were 11 year olds.

Pilot Reliability Study

A total of 14 subjects participated in an initial practice session. Participants were subjected to tests on two occasions which were identical to the tests performed in the study. The researchers practiced a variety of skills including palpation techniques, use of the Stabilizer Pressure Biofeedback Unit, and testing procedures.

Following the practice session, a pilot study was conducted with eleven subjects. All participants performed each of the testing procedures on two separate occasions. An attempt was made to reproduce an identical testing environment for each trial. The correlation coefficients for reliability of the testing procedures used in the study are shown in Table 1.
Reliability coefficients were defined as the following (Portney & Watkins, 1993).

- 0.00 - 0.25: little/no relation
- 0.25 - 0.50: fair reliability
- 0.50 - 0.75: moderate to good reliability
- 0.75 - 1.00: good to excellent reliability

Table 1

**Pilot Study Test- Retest Reliability (n =11)**

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<tr>
<th></th>
<th>Correlation Coefficient</th>
<th>P-value</th>
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<tr>
<td>Degree of Lordosis Prior to Testing</td>
<td>r = .73</td>
<td>p = .01</td>
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<tr>
<td>Upper Abdominal Strength</td>
<td>r = 1.00</td>
<td>p = .00</td>
</tr>
<tr>
<td>Lower Abdominal Strength</td>
<td>r = .34</td>
<td>p = .32</td>
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<tr>
<td>Fitness Test Abdominal Scores</td>
<td>r = .87</td>
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<tr>
<td>Degree of Lordosis After Testing</td>
<td>r = .45</td>
<td>p = .16</td>
</tr>
</tbody>
</table>

A p-value of ≤ 0.05 was considered acceptable for the purposes of this study.

**Subject Testing Results**

Software titled SPSS 6.1 for Windows was used to analyze the data. During the lower abdominal test subjects achieved a score ranging from 1-6. These scores indicated fair to normal lower abdominal strength (Table 2). For data analysis purposes, if subjects demonstrated normal to good strength (scores of 1, 2, or 3), they were grouped into a “strong” lower abdominal category. Subjects scoring good minus
to fair strength (scores of 4, 5, or 6) were placed in the “weak” lower abdominal category (Table 3).

Table 2

<table>
<thead>
<tr>
<th>Grades</th>
<th></th>
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<tr>
<td>Normal</td>
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</tr>
<tr>
<td>Good +</td>
<td>2</td>
</tr>
<tr>
<td>Good</td>
<td>3</td>
</tr>
<tr>
<td>Good -</td>
<td>4</td>
</tr>
<tr>
<td>Fair +</td>
<td>5</td>
</tr>
<tr>
<td>Fair</td>
<td>6</td>
</tr>
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Table 3

<table>
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<th>Categories</th>
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</thead>
<tbody>
<tr>
<td>1, 2, 3 = strong abdominals</td>
<td></td>
</tr>
<tr>
<td>4, 5, 6 = weak abdominals</td>
<td></td>
</tr>
</tbody>
</table>

Frequencies observed for the Kendall Lower Abdominal Strength Test determined that 44.4% of the subjects scored good minus strength, 30.2% scored fair plus strength, and 1.6% scored fair strength (Figure 1). Subjects with “strong” lower abdominals composed 23.8% of the total subject pool, while 76.2% demonstrated “weak” lower abdominals.

Figure 1. Distribution of Kendall Lower Abdominal Strength Results

The frequencies for the Kendall Upper Abdominal Strength Test fell predominantly into a single category. Normal upper abdominal strength was
demonstrated by 98.4% (62) of the subjects, where as only one subject demonstrated fair strength.

Descriptive statistics for the Presidential Physical Fitness Abdominal Test and degree of lumbar lordosis were also calculated. The mean score on the Presidential Physical Fitness Abdominal Test was 29.57 sit-ups/min with a standard deviation of 5.79. The Presidential Physical Fitness Council has established standardized abdominal scores for students achieving the 50th percentile. In the 10-11 year old age group, females who perform 30 sit-ups/minute and males who perform 35 sit-ups/minute achieve the criteria for the 50th percentile ranking. The number of sit-ups students performed in the study ranged from 18-40 in one minute. Figure 2 shows the distribution of sit-up scores achieved by the students.

Figure 2. Distribution of Presidential Physical Fitness Abdominal Scores

umbar lordosis measurements was calculated before and after the abdominal testing procedures. The degree of lumbar lordosis measured prior to abdominal testing averaged 47.70° (SD = ± 10.99) for 10 year olds and 49.47° (SD = ± 10.20) for 11
year olds. The degree of lumbar lordosis following abdominal testing demonstrated an average of 47.01° (SD = ± 8.89) for 10 year olds and 51.33° (SD = ± 9.12) for 11 year olds. The researchers attribute the differences in the lordosis measurements taken before and after testing to measurement error and subject variability. According to the Cobb method of measuring lumbar lordosis, the normal range for 10 year olds is 31.29° to 48.97° and 42.06° to 58.32° for 11 year olds (Chemukha, 1998). Figure 3 demonstrates lordosis measurements and groups students into below normal lordosis (1), normal lordosis (2), and above normal lumbar lordosis (3) categories according to age.

Figure 3. Degrees of lumbar lordosis categorized into:
1 = below normal curvature 2 = normal curvature
3 = above normal curvature

1 = < 31.29° for 10 y.o. & < 42.06° for 11 y.o.
2 = 31.29° to 48.97° for 10 y.o. & 42.06° to 58.32° for 11 y.o.
3 = > 48.97° for 10 y.o. and > 58.32° for 11 y.o.

To test the first hypothesis, a Chi-square was used to determine an association between the Presidential Physical Fitness Abdominal Test and the Kendall Lower Abdominal Strength Test. The Presidential Physical Fitness Abdominal Test results
were categorized into “fit” or “non-fit” abdominal strength groups. The categories were determined according to the 50th percentile standard devised by the Presidential Physical Fitness Council. Subjects falling below the 50th percentile were considered “non-fit”, while those performing at or above that level were labeled “fit.”. The “fit” category was defined as males scoring ≥ 35 sit-ups/min. and females scoring ≥ 30 sit-ups/min. The “non-fit” category was defined as males scoring < 35 sit-ups/min. and females scoring < 30 sit-ups/min. “Non-fit” scores were obtained by 33 subjects and “fit” scores were obtained by 30 subjects.

The significance of the data was determined by the Pearson Chi-square value. The results were compared with an alpha level of < 0.05. No statistical significance between the Presidential Physical Fitness test and the Kendall Lower Abdominal Strength Test was shown (See Table 4).

Table 4

<table>
<thead>
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<th>Number of Subjects</th>
<th>Pearson Chi-square Value</th>
<th>DF</th>
<th>Significance</th>
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</thead>
<tbody>
<tr>
<td>63</td>
<td>.58815</td>
<td>1</td>
<td>No</td>
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The second hypothesis proved to be statistically untestable. Normal upper abdominal strength was displayed by 98.4% of the subjects regardless of their score on
the Presidential Physical Fitness Abdominal Test. Therefore, there was no means for comparison between the groups that achieved the 50th percentile of the Presidential Physical Fitness Abdominal Test and those that did not.

The third hypothesis was analyzed using a Chi-square to demonstrate a relationship between the Presidential Physical Fitness Abdominal Test categories as stated in Table 3 and lumbar lordotic posture as defined in Figure 3. The data was compared with an alpha level of $\leq 0.05$ to prove statistical significance. No statistical significance was found between the two variables (See Table 5).

Table 5

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Pearson Chi-Square Value</th>
<th>DF</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>63</td>
<td>2.06</td>
<td>1</td>
<td>.15103</td>
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</tbody>
</table>

The fourth hypothesis was tested using a Chi-square to demonstrate a relationship between the Kendall Lower Abdominal Strength Test categories (Table 2) and lumbar lordotic posture categories (Figure 3). An alpha level of $\leq 0.05$ was used to measure statistical significance. No statistical significance was demonstrated between the two variables (See Table 6).
Table 6

Subject Testing Results of the Kendall Lower Abdominal Test Compared to an Increase in the Degree of Lumbar Lordosis (n = 63)

<table>
<thead>
<tr>
<th>Number of Subjects</th>
<th>Pearson Chi-Square Value</th>
<th>DF</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
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CHAPTER 5
DISCUSSION

Summary of the Results

No statistical significance was found between the Presidential Physical Fitness Abdominal test results and the Kendall Lower Abdominal Test results. A relationship between the Kendall Upper Abdominal Test and the Presidential Physical Fitness Abdominal test was found to be statistically untestable. Statistical significance was also not proven between increased lumbar lordosis and the Presidential Physical Fitness Abdominal test results. There was no relationship that proved statistically significant between increased lumbar lordosis and the results from the Kendall Lower Abdominal Test.

Results in Relationship to Previous Research

Nissinen et al. concluded that females with low back pain demonstrate an increased lumbar lordosis compared to females that are asymptomatic (1994). Increased lumbar lordotic posture was found in 30.2% (19) of females in the study. A conclusion may be drawn that the lower abdominal strength in 10 to 11 year olds has not been a focus of fitness testing or abdominal strengthening and conditioning in physical education classes. The results demonstrate the importance of prevention in treating low back pain. The literature demonstrates that low back pain in children beginning at an early age may often lead to low back pain in adulthood (Taimela, S., Kujala, U., Salminen, J., & Viljanen, T., 1997). Considering these conclusions and the observations made in this study, a number of female participants may be at risk of
developing a low back condition at some point in their lives. The number at risk could be drastically reduced if the subjects were trained to perform abdominal exercises that would strengthen the lower abdominals, including the internal and external obliques, to promote a more ideal spinal stabilization system.

Richardson and Jull have proven that the internal obliques, external obliques and transversus abdominis act together to stabilize the trunk (1995). These muscles work in synergy with the multifidi, as where the rectus abdominis has been found to inhibit the action of the multifidi (Richardson & Jull, 1995). The multifidi and the lateral abdominal muscle groups are the primary stabilizers of the spine. People with low back pain demonstrate decreased activity of these stabilizer groups (Richardson & Jull, 1995).

The leg lowering test was found to primarily facilitate the action of the external obliques, internal obliques, and transverse abdominis. The rectus abdominis fires minimally during the leg lowering test (Shields & Heiss, 1997). According to our study, “weak” lower abdominals were demonstrated by 76.2% of the subjects when performing the Kendall Leg Lowering Abdominal Test, and 24% were categorized as having “strong” lower abdominal results. The results suggest approximately 3/4 of the subjects lack optimal trunk stabilization. The literature states that the bent-knee sit-up primarily emphasizes activity of the upper abdominals. Of the children tested in this study, 98.4% displayed good to normal upper abdominal strength according to the Kendall Upper Abdominal Strength Test.
According to The President’s Council on Physical Fitness and Sports, an increased lumbar lordosis in the pre-adolescent period should not be considered abnormal (1975). Arthropometric factors in this age group could account for the varying degrees of lumbar lordosis found in the study. A normal lordotic curve was found in 57.1% (36) of the subjects, while 30.2% (19) of the subjects were found to have an increased lordosis. Considering the large number of subjects with a “normal” lordotic curve, more research needs to be conducted in this area to establish true normals for the pre-adolescent growth period.

The second hypothesis was untestable because 98.4% of the subjects demonstrated “good” or “normal” results on Kendall Upper Abdominal Strength Test, regardless of the results on the lower abdominal and fitness tests. The results strongly suggest that the upper abdominals are strong in 10 and 11 year olds and are not a large contributor to lordotic posture. The fitness test is used to assess abdominal strength in schoolchildren. This test has been proven to primarily test the rectus abdominis which acts to flex the vertebral column (Kendall et al., 1993). The rectus abdominis runs longitudinally along the anterior aspect of the trunk. It originates at the pubic crest and symphysis and inserts into the costal cartilages of the fifth-seventh ribs and xiphoid process of the sternum to approximate the trunk toward the pelvis (Kendall et al., 1993). The orientation of the muscle fibers does not allow for any rotational component during the primary motion of trunk flexion. This may provide an explanation for the decreased contribution of the rectus abdominis in controlling the degree of lumbar lordosis. Unfortunately, the fitness test does not challenge the
external and internal obliques that serve to stabilize the trunk (Richardson et al., 1990).

Results of our study indicate that 52.4% (33) of the subjects were categorized as having unfit abdominal strength and performed below the 50th percentile standard set by The Presidential Physical Fitness Council. In 1954, a study was conducted to evaluate the fitness levels of youth. It was discovered that 60% of school age children failed at least one portion of fitness test batteries (Corbin & Pangrazi, 1992). It may be concluded that regardless of the fitness programs implemented into the school curriculum since 1966, abdominal strength continues to be below the standards set by governing agencies.

Strengths

Prior to official data collection, the researchers performed a practice study with fourteen subjects. In addition to the practice study, a pilot study was run with eleven subjects. The researchers collected data from a subject pool diverse in background, activity level, geographical location and ethnicity. Data was collected from two schools. The majority of the subjects from one school were Caucasian while the other school provided predominantly African American subjects. In addition to subject variability, the large number of subjects included in the data collection also added to the study.

The abdominal tests chosen are reproducible. The detailed description of the tests provided in the appendices allow for the research study to be easily replicated by other researchers. Researchers consistently performed the same tasks and
measurements during the testing procedure. Consistent manual cues, verbal instructions, and demonstration were also provided to each subject.

Certain aspects of the study design added to the overall strength of the research. The researchers attempted to objectively control pelvic position during the leg lowering test using the Stabilizer. In addition to the Stabilizer, a lower abdominal scoring chart was used in place of a goniometer to score the test. Prescreen flexibility tests were run to ensure the subjects' ability to adequately perform the abdominal strength tests in the appropriate position. During the Presidential Physical Fitness Abdominal Test, the examiners were cautious to monitor the quality of the movement performed and the subject position.

Subjects were provided with a five minute rest period between each abdominal test. The rest period removed the possibility of fatigue interfering with the abdominal strength test results. Following the testing procedures, many students and faculty inquired about the purpose of tests and significance of the results. Performing the research study in schools, provided the opportunity for participants to ask questions regarding their abdominal musculature and learn how to appropriately strengthen their trunk. The researchers were also asked to give suggestions and recommendations for appropriate abdominal strength exercises. The researchers took the time to provide the requested information and demonstrate exercises with appropriate modifications.
**Limitations of the Study**

A significant number of student's that participated in the pilot study improved their lower abdominal strength test scores by one to two grades. Because this was an unfamiliar test for the subjects, their scores tended to improve on the second trial after the subjects practiced and became familiar with the testing procedure. This could have introduced the possibility of a learning curve into the pilot study. To support the effects of a learning curve, the subjects performed consistently on the tests they were familiar with, such as the Presidential Physical Fitness Abdominal test and improved on the tests they were unfamiliar with, such as the Kendall Lower Abdominal Muscle Test (Portney & Watkins, 1993).

Encouraging the participants to perform well was not emphasized during the Presidential Physical Fitness Abdominal Test. Motivation could have affected the results of the test because the students were not given significant verbal cueing that is typically done when the test is performed in the schools. Researchers only provided verbal cues toward the subjects when technique or position during the sit-ups required correction. It was also observed that some of the subjects appeared to be concerned about performing the sit-ups in front of their peers. Other subjects seemed to not give their best effort and at times appeared to have given up before the test was over. Some subjects performed the sit-up test in a competitive nature. Occasionally, two subjects performed the test simultaneously while others were motivated by previous scores achieved by their peers.
The randomization of subject selection, unfortunately yielded more female than male participants. In addition to the unequal sex distribution, the male participants appeared to be more concerned with how their results compared to their peers. Because students were not categorized according to their athletic ability, it is possible that the subject pool was unevenly distributed between athletes and non-athletes. Student athletes may have performed better due to their participation in athletic activities.

Subjects tested were between ten and eleven years old. This age group was initially selected because of the relationship of the normalization of the spinal curves. Further research has revealed that growth and developmental factors in this age group may impact the leg lowering strength test. As adolescence approaches and children begin to experience growth spurts of varying degrees the leg length can exceed the trunk length. The difference in leg length may increase the difficulty of the test. Literature suggests that a strength grade of fair plus or good minus in adolescence should be considered a normal score (Kendall et al., 1993). Arthropometric factors may have also influenced the results of the abdominal testing. Students with endomorphic body types and those females entering puberty early may be at a disadvantage when performing the leg lowering test because of their body distribution. Males and ectomorphic females will have an advantage when performing the leg lowering strength test because of their leg length and trunk distribution.

The flexicurve measurement tool also introduced a number of limitations into the study. The tool was found to be extremely sensitive when used in conjunction
with the formula for calculating the degree of lordosis. Small increments of measurements were found to produce significant error when calculating curvature of the lumbar spine. For example, a finger tips width of error, which represented approximately 10 cm, accounted for between 10-20 degrees of variability in the lumbar lordosis measurement. Novice palpation skills and occasional difficulty working around clothing added to the degree of error. Transferring the Flexicurve from the subject to the data sheet, also allowed for errors due to the bendible nature of the measuring tool. It was also observed by the researchers that apprehension towards this part of the testing procedure was felt by some subjects. Occassionally, subjects needed to be reminded to stand in a natural posture possibly due to their apprehension.

The degree of lumbar lordosis measured by the Flexicurve was categorized into increased, normal and decreased lordosis. The formula used to calculate the degree of lumbar lordosis produced degrees to the nearest hundredth. Some of the subjects lordosis measurements were borderline between the categories by only a few hundredths of a degree. Therefore, subjects categorized as having a normal lordosis can numerically be closer to an increased or decreased curve.

The Stabilizer Pressure Biofeedback Unit was not anatomically placed in a consistent manner. The researchers placed the unit where the lower back met the floor when the subject was in long sitting position. Due to inconsistencies in body types, it is possible that the pillow was not in the same position on each subject. Smaller body types appeared to have difficulty holding the test position when 40 mmHg of pressure was in the unit. The researchers attempted to reduce the pressure for subjects when
the position of the pelvis was being influenced by the amount of air in the pressure
cuff:

Suggestions for Further Research

One suggestion for further research, would be to test 14-16 year old males and
females. This may minimize the effects of growth factors on test results. The growth
spurts that occur before this age produce disproportionate trunk to leg length ratios
that may influence the results of the study. The interpretation of data may mislead the
readers into believing that weaknesses are present when in actuality the data is a result
of normal growth changes for 10 to 11 year old subjects.

Further objectivity of the study may be obtained through the use of EMG
electrodes placed on the transverse abdominals, rectus abdominals, and internal and
external obliques during the three abdominal strength tests. EMG results may enhance
the validity of the tests.

An experimental study would also prove helpful. Students could be grouped in
control and experimental groups at the beginning of a school year. All students would
participate in baseline abdominal testing. An intervention group would receive
prescribed exercises by the researchers to specifically strengthen the transverse and
rectus abdominal muscles, as well as the internal and external obliques. The control
group would participate in the specified physical education curriculum of the school.
At the end of the school year, all subjects would be retested with the identical baseline
abdominal testing used at the beginning of the study. Results could then be correlated
with improvements gained in strengthening the targeted muscle groups.
Another possible research idea would be to integrate the flexible ruler measurement of spinal curvature with the above stated experimental and control groups. Tracings of the subjects’ spinal curves from C7 to S2 could be transferred to a transparent sheet for visual observation. Due to compounding factors with the Flexicurve measurements, observational comparisons could detect subtle changes in curvature. After completion of the abdominal strengthening intervention with the experimental group, another tracing would be performed. The tracings would be superimposed upon one another to compare results without the use of exact measurements. This would decrease error by eliminating the need for skilled palpation and precise measurements utilizing small dimensions.

A test comparing concentric versus eccentric abdominal strengthening exercises utilizing EMG electrodes placed at the transversus abdominis, rectus abdominis, and internal and external obliques could objectively monitor muscle activity. The results of the EMG analysis could be used to differentiate the exercises which predominantly utilize the transverse abdominals and the obliques. Current research has suggested that these muscle groups work in synergy with the multifidi to stabilize the spine (Richardson & Jull, 1995). In contrast, the upper rectus abdominals have been shown to inhibit the stabilizing effects of the multifidi by acting as an antagonist (Richardson & Jull, 1995).

**Conclusions and Recommendations**

Although the results of the study were not statistically significant, it is important for physical educators to continually examine the exercise programs they
establish for children. Physical education activities such as the sit-up and curl-up exercises promote poor coordination of muscle activity. Exercises should focus on rotation and lateral flexion activities to train appropriate spinal stabilization. Lower abdominals can be trained during the eccentric phase of the curl-up without the feet being held down (Miller & Medeiros, 1987). Various forms of the leg lowering test can be implemented due to the difficulty with the double leg lowering test (Gilleard & Brown, 1994). Most importantly, a variety of trunk side flexion as well as internal and external oblique activities should be performed.

It is also important for physical educators to emphasize the quality of movement instead of the quantity of movement activities performed. In this study, the average score on the Presidential Physical Fitness Abdominal Test was 29.57 +/- 5.79. Many subjects in this study scored at or below this level. Few subjects actually achieved the 50th percentile qualifying standard needed to receive the Presidential Physical Fitness Award. The high number of sit-ups needed to achieve this level of abdominal fitness is an unrealistic goal for many children. Using momentum, substituting muscle groups, and incorporating inappropriate muscle activity are often the only means available to achieve these kind of results. Physical educators should train abdominal muscles emphasizing the quality of the movement pattern as opposed to the speed of the activity performed.

The results of the Kendall Upper Abdominal Strength test indicate that this particular age population has adequate strength of the upper rectus abdominis. Tests such as the bent-knee sit-up are typically overemphasized in fitness programs in
elementary schools. One may conclude based on results of this study that the upper abdominals are sufficiently facilitated through everyday activity or through exercise programs that are already incorporated into school programs. As research has proven, exercises which promote the use of the lateral abdominal muscle groups as well as the rotators of the trunk and spine should be implemented into existing physical education classes. Programs which implement the training of these muscle groups may decrease the risk of future low back injuries and promote health awareness.

In 1997, the American Physical Therapy Association (APTA) Board of Directors revised the definition of physical therapy to include, “preventing injury, impairments, functional limitations and disability, including the promotion and maintenance of fitness, health, and quality of life in all age populations.” (Thompson, 1997). This definition represents the current vision for physical therapists to redefine roles and examine the profession's benefit in areas of prevention and wellness.

The intent of this study was to promote primary and secondary prevention in the area of low back pain. The primary preventative measure that may be taken from this study was to educate adolescents and physical education instructors in appropriate abdominal exercises to adequately stabilize the trunk. By utilizing the Flexicurve to detect abnormal lordotic postures, a new mechanism for early screening and diagnosis may have been introduced by this study.

In regards to the changes occurring in the health care field, it is important for the physical therapy profession to recognize their critical role in prevention and education. Rehabilitation must be flexible and open to expanding professional
opportunities in this arena. The traditional philosophy of intervening following an injury, pathology, or disability needs to be re-examined. Physical therapists may have an integral role in providing care, education and consultation prior to the occurrence of these events. This study was written to attempt to prove the need for prevention in populations as young as 10-11 years old.

More research needs to be performed to produce outcome data in preventative health care. Many physical therapists support prevention and wellness programs in the community. Physical therapists are well prepared academically and clinically to recognize, evaluate, and treat dysfunction before impairment or disability occurs. Unfortunately, evidence is lacking to support the positive impact of such programs in improving an individual’s quality of life (APTA, 1995).
REFERENCES


APPENDIX A

Kendall Upper Abdominal Test

Anterior Trunk Flexors: Upper Abdominal Muscle Test

ANALYSIS OF THE TRUNK-RAISING MOVEMENT

Preliminary to doing this test, test the flexibility of the back so that restriction of motion is not interpreted as muscle weakness.

The trunk-raising movement, properly done as a test, consists of two parts: Spine flexion (trunk curl), and hip flexion (sit-up).

During the trunk curl phase, the abdominal muscles contract and shorten, flexing the spine. The upper back rounds, the low back flattens, and the pelvis tilts posteriorly. At the completion of the curl, the spine is fully flexed with the low back and pelvis still flat on the table. The abdominal muscles act to flex the spine only. During this phase, heels should remain in contact with the table.

The trunk curl is followed by the hip flexion phase during which the hip flexors contract and shorten lifting the trunk and pelvis up from the table by flexion at the hip joints, pulling the pelvis in the direction of anterior tilt. Since abdominal muscles do not cross the hip joints, they cannot assist in the sit-up movement but, if strong enough, they continue to hold the trunk curled.

The hip flexion phase is included in the test because it provides resistance against the abdominal muscles. The crucial point in the test is the moment that movement enters the hip flexion phase.

It is at this point that, for some, the feet may start to come up from the table and may be held down if the force exerted by the extended lower extremities does not counterbalance the force exerted by the flexed trunk. If the feet are held down, attention must be focused on whether the trunk maintains the curl, because it is at this point that the strong resistance offered by the hip flexors can overcome the ability of the abdominals to maintain the curl. If this occurs, the pelvis will quickly tilt anteriorly, the back will arch, and the subject will continue the sit-up movement with the feet stabilized.

TEST FOR UPPER ABDOMINAL MUSCLES

Patient: Supine, legs extended. If hip flexor muscles are short and prevent posterior pelvic tilt with flattening of the lumbar spine, place a roll under the knees to passively flex the hips enough to allow the back to flatten. (Arm positions are described below under Grading.)

Fixation: None necessary during the initial phase of the test (i.e., the trunk curl) in which the spine is flexed and the thorax and pelvis are approximated. Do not hold the feet down during the trunk curl phase. Stabilization of the feet will allow hip flexors to initiate trunk raising by flexing the pelvis on the thighs.

Test Movement: Have the subject do a trunk curl slowly, completing spine flexion (thereby completing the range of motion that can be performed by the abdominal muscles). Without interrupting the movement, the subject continues into the hip flexion phase (the sit-up) for the purpose of obtaining strong resistance against the abdominal muscles in order to obtain an adequate strength test.

Resistance: During the trunk curl phase, resistance is offered by the weight of the head, upper trunk, and arms which are placed in various positions for purposes of grading. However, the resistance offered by the weight of the head, shoulders, and arms (placed in various positions to increase resistance) is not sufficient to provide an adequate test for strength of the abdominal muscles.

The hip flexion phase provides strong resistance against the abdominals because the hip flexors pull strongly downward on the pelvis as the abdominals work to hold the pelvis in the direction of posterior tilt. (See facing page.)

Grading: (See facing page.)
Grading 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 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 (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 unable to maintain the flexion when attempting to enter the hip-flexion phase.

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

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.

*See numerical equivalents for + symbols used in grading, p. 188, and Key to Muscle Grading, p. 189.
ANTERIOR ABDOMINAL MUSCLES, MAINLY RECTUS ABDOMINIS

Fair (4): In supine position with knees slightly flexed (rolled towel under knees), the patient is able to tilt the pelvis posteriorly and keep the pelvis and thorax approximated as the head is raised from the table.

Poor (2): In the same position as above the patient is able to tilt the pelvis posteriorly, but as the head is raised the abdominal muscles cannot hold against that resistance anteriorly, and the thorax moves away from the pelvis.

Trace: In the supine position, when patient attempts to depress the chest or tilt the pelvis posteriorly, a contraction can be felt in the anterior abdominal muscles, but there is no approximation of the pelvis and thorax.
APPENDIX B
Kendall Lower Abdominal Test

Anterior Trunk Flexors: Lower Abdominal Muscle Test

Anterior trunk flexion by lower abdominal muscles focuses on the ability of these muscles to flex the lumbar spine by flattening the low back on the table, and holding it flat against the gradually increasing resistance provided by the leg-lowering movement.

Patient: Supine on a firm surface. A folded blanket may be used, but no soft pad. Forearms are folded across the chest to ensure that the elbows are not resting on the table for support.

Fixation: None should be applied to the trunk because the test is to determine the ability of the abdominal muscles to fix the pelvis in approximation to the thorax against resistance by the leg lowering. Giving stabilization to the trunk would be giving assistance. Allowing the patient to hold on to the table, or to rest hands or elbows on the table would also provide assistance.

Test: The examiner assists the patient in raising legs to a vertical position, or has the patient raise them one at a time to that position, keeping the knees straight. (Hamstring tightness will interfere with obtaining the full starting position.)

Have the subject tilt the pelvis posteriorly to flatten the low back on the table by contracting the abdominal muscles, and hold it flat while slowly lowering the legs. Attention is focused on the position of the low back and pelvis as the legs are lowered. The subject should not raise the head and shoulders during the test.

Resistance: The force exerted by the hip flexors and the lowering of the legs tends to tilt the pelvis anteriorly and acts as a strong resistance against the abdominal muscles which are attempting to hold the pelvis in posterior tilt. As the legs are lowered by the eccentric (lengthening) contraction of the hip flexors, leverage increases and provides increasing resistance against the abdominal muscles for the purpose of grading the strength of these muscles.

Grading: Strength is graded based on the ability to keep the low back flat on the table while slowly lowering both legs from the vertical (90° angle).

The angle between the extended legs and the table is noted at the moment that the pelvis starts to tilt anteriorly and the low back arches from the table. To help detect the moment this occurs, the examiner may place one hand on the low back and the other hand with the thumb just below the anterior-superior spine of the ilium. However, when testing patients with weakness or pain, place the thumb of one hand just below the anterior-superior spine and leave the other hand free to support the legs the moment the back starts to arch.

The leg-lowering test for abdominal strength is not applicable to young children. The weight of the legs is small in relation to the trunk and the back does not arch as legs are raised or lowered. Furthermore, at the age of 6 or 7 years, when the test would have some significance, it is not easy for a child to differentiate muscle action and try to hold the back flat while lowering their legs. From about age 8 or 10 years, it is possible to use the test for many children. As adolescence approaches and the legs grow long in relation to the trunk, the picture reverses from that of early childhood and the leverage exerted by the legs and they are lowered is greater in relation to the trunk. At this age, grades of fair + or good – on the leg-lowering tests should be considered "normal for age" for many children, especially those who have grown tall very quickly. After the age of 14 to 16, males should have the strength to grade normal, and females should grade good. Because of the distribution of body weight, men have an advantage in the leg-lowering test, and women have an advantage in the trunk-raising test.
Grading 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.)
APPENDIX C

Research Proposal

The Effects of Abdominal Strength Exercises and Testing on Posture in Schoolchildren

INTRODUCTION/THEORETICAL CONSTRUCT

Many school systems incorporate testing to evaluate the physical fitness of children. Abdominal strength and endurance are commonly assessed by fitness tests. The Presidential Physical Fitness test battery is one program which advocates using the bent-knee sit-up as a test component and as a practice tool. The test encourages the participant to perform a maximum number of sit-ups in sixty seconds. Instead of focusing on the quality of movement, the test emphasizes performance. Children with weak abdominal musculature may pass the test with high scores by utilizing the hip flexors and arching the low back. This exercise may contribute to a muscle imbalance between the trunk flexors and trunk extensors. Stretched and weakened abdominals and shortened hip flexors and lumbar extensors, lead to an increased anterior pelvic tilt and lumbar lordosis. This posture increases the stress and shear forces to the lower back, resulting in pain.

Some adolescents begin to experience low back pain at 13 to 14 years of age and the prevalence tends to increase with aging. Research suggests that low back pain in the adolescent period is associated with an increased frequency of low back pain in adults. Since a treatment for low back pain has not been proven, it seems logical to prevent the condition. Schoolchildren are an appropriate population to target for intervention because postural habits and exercise techniques are developing during this period. Physical therapists are not currently employed to assess normal development in school children. Physical therapists are prepared to assess musculoskeletal development and implement preventative measures, including wellness programs for schoolchildren.

The purpose of this study will be to measure the strength of the abdominals with the Presidential Physical Fitness Abdominal test and Kendall’s version of measuring upper and lower abdominal strength. The abdominal strength test results will be compared and correlated with lumbar posture. The hypotheses that will be tested are:

1) Male students with scores of 35 or greater and female students with scores of 30 or greater on the Presidential Physical Fitness Abdominal test will demonstrate good (-) to fair strength on the Kendall Lower Abdominal Muscle test.

2) Male students with scores of 35 or greater and female students with scores of 30 or greater on the Presidential Physical Fitness Abdominal test will demonstrate good to normal results on the Kendall Upper Abdominal Muscle Test.
3) Male students with scores of 35 or greater and female students with scores of 30 or greater on the Presidential Physical Fitness Abdominal test will be positively correlated to increased lordotic posture (r<0.05).

4) Students with Good (-) to Fair scores on the Kendall Lower Abdominal Muscle Test will be positively correlated to increased lordotic posture (r<0.05).

METHOD

All subjects (n≥75) ages 10-11 years old will be selected from local elementary schools in the Grand Rapids area. All subjects and parents will sign informed consent prior to participation in the study. All subjects will meet the following inclusion criteria:

Inclusion criteria:

1. Subjects will demonstrate the ability to perform a posterior pelvic tilt.
2. Subjects must be in good general health.
3. Subjects must be able to achieve a 90 degree straight leg raise.
4. Subjects must be able to follow basic directions required to achieve objectives of the study.
5. Subjects will have no history of back pain within the past 12 months.
6. Subjects must have no present spinal pathologies.
7. Subjects must have no history of lower extremity pathologies within the past 12 months.
8. Subjects must have no history of lower extremity/abdominal surgery within the past 24 months.

VARIABLES

Independent: 1) Kendall’s Upper Abdominal muscle strength results
2) Kendall’s Lower Abdominal muscle strength results
3) Presidential Physical Fitness Abdominal strength results

Dependent: 1) Degree of lumbar lordosis

ATTRIBUTES (data type)

1) Kendall’s Upper Abdominal muscle strength (ordinal/ranked)
2) Kendall’s Lower Abdominal muscle strength (ordinal/ranked)
3) Presidential Physical Fitness Abdominal strength (ordinal/ranked)
4) Degree of lumbar lordosis (interval)
OPERATIONAL DEFINITIONS

**Bent-knee sit-up**-is defined as the movement of coming from a supine to a sitting position with the hip joints flexed and the knees bent to a 90° angle with the ankles no further than 12 inches from the buttocks, a partner braces the subject at the ankles during the exercise (President's Council on Youth Fitness and Sports, 1985)

**Muscle imbalance**-inequality in strength in opposing muscles; a state of muscle imbalance exists when a muscle is weak and its antagonist is strong leading to faults in alignment and inefficient movement (Kendall, 1993)

**Anterior pelvic tilt**-a position of the pelvis in which the vertical plane through the anterior-superior spines is anterior to the vertical plane through the symphysis pubis (Kendall, 1993)

**Posterior pelvic tilt**-pelvic tilt in which the vertical plane through the anterior-superior spines is posterior to the vertical plane through the symphysis pubis (Kendall, 1993)

**Lumbar lordosis**-is characterized by an increased lumbosacral angle (greater than 30°), an increased anterior pelvic tilt, and hip flexion; the following structures are elongated and weak: anterior abdominals (rectus abdominis, internal and external obliques); hamstrings may lengthen initially but after some time shorten to compensate for the posture; the following structures are short and strong: hip flexors (iliopsoas, tensor fascia latae, and rectus femoris), and lumbar extensors (erector spinae) (Kendall, 1993 and Kisner, 1990)

**Kendall Lower Abdominal Test**-according to Kendall et al (1993)

**Kendall Upper Abdominal Test**-according to Kendall et al (1993)

**Presidential Physical Fitness Abdominal Test**-according to the President's Council on Physical Fitness and Sports (1985)

**Good general health**-is not having an illness/injury/infection which require the student to be absent for a full school day

**90° Straight Leg Raise Test**-according to Magee (1992)

**Ability to follow basic directions**-defined as the ability to perform all tasks required with less than 3 explanations or demonstrations
Low back pain-is defined as any pain and/or discomfort presently occurring in the low back region or a previous episode with a duration greater than 3 days within the last school year that required a change in activity level or medical attention.

Spinal pathologies-consists of any of the following: scoliosis, disc herniation, Scheuermann's disease, juvenile kyphosis, spinal tumors, and vertebral epiphysitis (Brashear, 1986).

Lower extremity pathologies-is defined as any pelvic, hip, knee, ankle, or foot condition in the past 12 months that required medical attention.

Abdominal/Lower Extremity Surgery-is defined as any abdominal surgery (i.e. appendectomy, hernia, or trauma that required surgical intervention) and/or lower extremity surgery involving the pelvis, hip, knee, ankle, or foot within the last 12 months.

PROCEDURE

Following an information session regarding the study, a brief history and prescreen examination will be administered. Testing begins with a postural assessment of the lumbar region, utilizing the Flexicurve. The upper abdominal strength test, lower abdominal strength test, and Presidential Physical Fitness abdominal test will be conducted in a randomized procedure with each participant. All participants will be given a 10 minute rest period between each of the 3 abdominal tests. Lower abdominal strength test will proceed according to Kendall (1993). During the test, one researcher will monitor the position of the pelvis and trunk with a device called the “Stabilizer” while the other will obtain a hip angle measurement utilizing Kendall’s lower abdominal strength measurement chart. The Presidential Physical Fitness Abdominal test will be administered according to the President’s Council on Physical Fitness and Sports (1985). Following abdominal tests and a 10 minute rest, a postural assessment of the lumbar region will be readministered, utilizing the Flexicurve. Participants will then be dismissed from the study and given the opportunity to ask any additional questions.

DATA ANALYSIS

A correlational, non-parametric analysis using a Spearman Rank Correlation Coefficient ($r \leq 0.05$) will demonstrate the relationship between the degree of lumbar lordosis and abdominal strength test results. The Kendall upper and lower abdominal tests and the Presidential Physical Fitness test will be compared utilizing the Mann-Whitney $U$ t-test (Portney and Watkins, 1993).
Lack of low back support allows uncontrolled spinal movement during many exercise routines. All those involved in exercise know it can be hazardous for the lumbar spine and risks causing low back strain, pain and injury.

The STABILIZER monitors the position of the low back and provides feedback to the client and the operator when the abdominal muscles are not actively or effectively protecting the spine.

The STABILIZER also monitors the accuracy and control of many muscle strengthening, stretching and re-education techniques. Never before has there been an easy and precise method of ensuring safe exercise.

The STABILIZER provides motivation while allowing for safe and precise progression of exercise.

A simple device to provide feedback to ensure safety, quality and precision in exercise performance and testing.

The STABILIZER is useful in most techniques. It’s most important application is helping prevent back strain and pain by:

- Retraining of abdominal musculature
- Postural training
- Monitoring of lumbar spine stabilization
- Stretching technique safety and precision

STABILIZER Tutorial Video
The 18 minute Tutorial Video features physiotherapists offering instruction in abdominal muscle and postural training; monitoring of lumbar spine; and safety and precision of muscle stretching techniques.

This STABILIZER Tutorial Video teaches you how to educate your patients/clients about the proper way to strengthen and stretch their muscles.

- A new dimension in muscle control and stabilization
- An essential tool for all concerned with quality exercise

ORDERING INFORMATION

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APPENDIX E

Flexicurve Instrument

1. Photograph of flexible rule
APPENDIX F

Informed Consent/Prescreen Questionnaire/Letter

Informed Consent

I, ________________, understand that my child ________________, will participate in a study involving abdominal strength testing, postural assessment, and flexibility testing. I realize this study is being conducted to help physical therapists, physical education teachers, and schools to utilize the most effective abdominal test to measure abdominal strength in school children. Abdominal strength has been related to posture and the incidence of low back pain in both adults and children. The intent of the researchers is to utilize the results of the study as a tool in the prevention of low back pain in children and adults. I also understand that:

1. My child’s participation in this study requires he/she perform a series of 3 abdominal strength tests and 2 flexibility measures. A 10 minute rest period will be provided between each strength test.

2. Following the strength tests, there will be a postural assessment utilizing an instrument called the Flexicurve. The Flexicurve is a flexible ruler that measures the spinal curve from middle of the back to the lower back. Use of this device will involve exposing the low back and upper pelvis.

3. Although, these exercises are safe for school-age children, there is a slight risk of low back injury when performing the abdominal strength test in an improper arched back position.

4. At completion of the study, your child may experience abdominal muscle soreness, lasting up to 48 hours. If the muscle soreness lasts longer than 48 hours, contact the researchers or a physician.

5. My child’s participation in the study will be kept strictly confidential. The data collected will be coded so participants in the study cannot be identified.

6. A summary of the results will be made available upon request.

7. My child’s participation in this study is completely voluntary and that my child can withdraw from the study at any time by contacting the researchers, without questions or consequences.

8. I acknowledge that my, as well my child’s, questions about the study have been answered to my satisfaction, and that I may continue to ask questions before, during and after my child’s participation. I have been given a contact person for information regarding the study and my child’s rights as a subject. In the event that
questions arise involving the participant's rights as a human subject, please contact Professor Paul Huizenga at 616-895-2472.

I acknowledge that I have read the above information and discussed it with my child, and based on this information, I am giving my child permission to participate in the study.

____________________________  ______________________
Parent's Signature              Date

____________________________  ______________________
Student's Signature             Date

____________________________  ______________________
Researcher Signature            Date

____________________________  ______________________
Researcher Signature            Date

Chairperson
Jolene Bennett, M.S., P.T., OCS, A.T.,C
(616)364-6484

Researcher
Greta McDonald, S.P.T.
(616)895-4438

Researcher
Kristin Nederveld, S.P.T.
(616)363-7141
**Prescreen Questionnaire**

Please answer the following questions and return this form with your child to school. The information provided will determine your child’s eligibility for participation in the study. All material will be confidential.

**Child’s Name:** ___________________________  **Date:** __________

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<th>Response</th>
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<td><strong>1. Has your child had an illness, injury, or infection that required immediate medical attention causing your child to be absent for a full day of school within the last 12 months?</strong></td>
<td>Yes</td>
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<tr>
<td><strong>2. Does your child have any present discomfort in their low back?</strong></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>3. Has your child had any previous episodes of low back pain with a duration greater than 3 days within the last 12 months which changed their activity level or required medical attention?</strong></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>4. Does your child have any of the following: scoliosis, disc herniation, Scheurmann’s disease, juvenile kyphosis, spinal tumors, or vertebral epiphysitis?</strong></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>5. Has your child had a history of pelvis, hip, leg, knee, ankle, or foot problems in the past 12 months which has required medical attention?</strong></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>6. Has your child had abdominal surgery within the last 12 months (i.e. appendectomy, hernia, or trauma which required surgical intervention)?</strong></td>
<td>Yes</td>
</tr>
<tr>
<td><strong>7. Has your child had surgery on the pelvis, hip, knee, ankle, or foot within the last 24 months?</strong></td>
<td>Yes</td>
</tr>
</tbody>
</table>

Please list name and address if you wish to receive a summary of the results, thank you.
Letter to Parent/Guardian

Dear Parent/Guardian and Student:

This letter is to inform you and your child of a fun, educational study which they have the opportunity to participate. Involvement in this study will give your child the chance to experience what it is like to be involved in the collection of data for a research study.

We are third year physical therapy students at Grand Valley State University working on our Master’s degree by completing a thesis. We chose to research elementary school children in the hopes of promoting better health and fitness habits in youth. Our study focuses on the effects of abdominal strength exercises and testing on low back posture. The results of our study will be useful in the prevention of low back pain as well as helpful to physical education teachers in developing fitness programs.

Your child’s 20-25 minute participation in the study will consist of strength testing of the abdominal muscles, examining flexibility of the back of the thigh, and assessing the posture of the low back. The strength testing will include an upper abdominal test, lower abdominal test, and a commonly utilized sit-up test known as the Presidential Physical Fitness Test.

The research study has been approved by Grand Valley State University’s Human Subject Review Board and a selected faculty committee with an interest in youth fitness. Procedures are not harmful to the child. Furthermore, your child may withdraw from the study at any time. If you or your child is interested in their results from the study, a summary of the results may be provided to you upon request.

We would greatly appreciate if you can give your child the opportunity to be involved in this fun experience. Please read, sign, and date the enclosed informed consent form, along with the prescreen questionnaire and send it to school with your child. If you have any questions or concerns please feel free to contact any personnel listed on the enclosed form. Thank you for your time and interest in our study.

Sincerely,

Greta McDonald, Student Physical Therapist

Kristin Nederveld, Student Physical Therapist
APPENDIX G

Instructional Script

Introduction:

We will begin testing by administering a flexibility test. The flexibility test will be followed by a quick posture assessment of your low back. The posture assessment will be performed with a device resembling a flexible ruler. Then you will perform 3 abdominal tests consisting of a sit-up, an upper abdominal strength test, and a lower abdominal strength test. You will be given a 5 minute resting period between exercises. The abdominal tests will be performed in a random order. Upon completion of the abdominal tests, we will perform another posture assessment of your low back.

Feel free to ask questions or withdraw from the study at any time during testing. If you are interested in seeing your results from the study, let one of us know at the completion of the testing.

Test:

1. Prescreen:
   a. Give the student a brief explanation of the purpose and goals of the study.
   b. “We chose to do research with your age group in hopes of promoting better health and fitness habits. Our study focuses on the effects of abdominal strength exercises and testing on low back posture. We hope the results will be useful in preventing low back pain and helpful to your physical education teachers in developing your exercise programs. The testing will take approximately 20-25 minutes.”
   c. Ask the student if they have any questions regarding any of the abdominal tests, posture assessment, or purpose of the study.
   d. Position the subject supine on a table with the hips and knees flexed.
   e. “Please grasp your legs above and behind the knee and slowly straighten your right leg as far as you can and then straighten your left leg as far as you can.”
   f. “If you feel any pain or discomfort while performing this exercise, please stop immediately.”
   g. Examiner will examine hamstring restriction according to the 90°-90° straight leg test. If restriction is greater than 20° from vertical, the subject will be dismissed and excluded from the study.

2. Flexicurve Measurement:
   a. Ask subjects who are wearing any obtrusive clothing (i.e.: belt, thick clothing wrapped around the waist, etc.) that would interfere with a flexicurve measurement to remove such clothing.
b. "Will you now please stand how you normally would with your back toward me in front of this table, while I get a curve measurement of your low back."

c. "I'm now going to lift up the back of your shirt and ask you to pull your shorts down just enough so that we can see your low back. We will now need to feel your back to find the landmarks for our measurement."

d. "If you feel like you are going to lose your balance while I am getting your curve measurement, feel free to hold onto the table in front of you."

e. Place the flexicurve so the top of the instrument is at L-1 and the end of the instrument is at S2, mold the flexicurve accordingly. Landmarks will be located according to Appendix.

f. "We are now finished with this portion of the test. Please wait just a minute while we trace the mold of your back on a piece of paper and then we will move on to the abdominal tests."

g. Examiner will trace the molded flexicurve on a piece of paper and label it with the participant's identification number.

Procedures 3-6 will be performed in a random order

3. Upper Abdominal Strength Test:
   a. "We will now be testing your upper abdominal strength. This exercise will be performed twice. Lie on the table on your back. Keeping your legs straight, bring your hands behind your head. Without using your hands or arching your back, curl your head and upper body first and then come up to a sitting position without jerking or bouncing. Now watch as we demonstrate the exercise for you."
   b. Examiners will demonstrate the upper abdominal strength test.
   c. "Do you have any questions before we start the test? You will be given one practice test before we actually score your performance."
   d. Examiners will answer questions if needed.
   e. If the student is able to get into the sitting position independently, they will be given a "normal (1)" on the data sheet for upper abdominal strength. If the student is unable to complete this exercise, they will continue with the following sequence until they are able to complete an exercise in a modified position. Once they complete the exercise in the modified position, they are given the corresponding score and the test is terminated.

   1. "Continuing to keep your legs straight, fold your arms across your chest and come up into the sitting position curling your head and upper chest first. We will now demonstrate the test for you."
   2. Examiners will demonstrate exercise.
   3. If the student completes this exercise independently, they are given a "Normal (1)" on the data sheet and the test is completed.
Students go to the next abdominal test. If they are unable to perform the previous exercise, go to step 4.

4. “Keeping your legs in the same position, bring your arms straight out in front of you and come up into the sitting position. We will now demonstrate this exercise for you.”

5. Examiners will demonstrate exercise.

6. If the student completes this exercise independently, they are given a “fair + (3)” on the data sheet and they move on to the next abdominal test. If they are unable to perform the previous exercise the test is modified again.

7. “With your arms straight forward, curl your upper chest up so that your shoulders are off the surface of the table and try to sit up with your legs straight.”

8. Examiners will demonstrate exercise.

9. If the student is able to complete all aspects of this exercise but can not maintain trunk flexion when attempting the hip-flexion phase, the subject will be given a “fair (4)” on the data sheet and they will move on to the next abdominal test.

10. Examiners will place subject in supine position with a towel roll under the knees.

11. “Flatten your back against the table and raise just your head.”

12. A “fair - (5)” will be given if the pelvis and thorax approximate. A “poor (6)” will be given if approximation does not occur.

13. 5-minute rest will be given.

4. Explanation and Use of Stabilizer Unit
   a. Show the subjects the Stabilizer unit. “We will be using this instrument to keep track off the position of your back during this exercise test. The stabilizer is similar to a blood pressure cuff, we will pump it up with air and place it under your low back.”

5. Lower Abdominal Test:
   a. “We will now begin to test your lower stomach for strength. We will run this test twice. Sit up straight with your legs straight out in front of you.”
   b. Examiners place the Stabilizer on the floor, against the subjects low back while in sitting.
   c. “Lie on your back with the legs straight and fold your arms across your chest.”
   d. One of the researchers will assist the students to raise their lower extremities so that the hips are flexed to 90 degrees and the knees are extended. The other researcher will line up the vertical 90° mark on the measurement chart with the vertical position of the subjects lower extremities.
e. "Flatten your back into the floor, while keeping your back flat, slowly lower your legs as far as you can before your back arches. We will catch your legs when we feel your back arch."

f. The hip angle will be measured at the point where they could no longer keep the back flat. This will be monitored by a rapid 8-10° drop in pressure measured by mmHg using the Stabilizer Unit and one of the examiners hands under the low back. Measurements will be given according to the corresponding angle of the measurement chart.

g. 5-minute rest will be given.

h. Repeat steps b-g.

6. The Presidential Physical Fitness Test

a. "We will be testing your overall stomach strength with the Presidential Physical Fitness test. This test is used in many schools to check fitness levels in children your age."

b. "Please lie with your back on the mat and bend your legs so that your feet are about 12 inches from your bottom."

c. Examiner will check distance of feet from buttocks and reposition the child’s feet if appropriate.

d. "Now cross your arms across your chest."

e. "When I say go, I want you to do as many sit-ups as you can in 1 minute. Raise yourself up high enough so your elbows touch the front of your legs. Do not bounce off of the floor. When I say stop, you can stop the test."

f. "Do you have any questions?"

g. Examiner will answer questions.

h. Examiner will set a stop watch for 60 seconds.

i. "Now we will begin the test. Ready, go."

j. Examiner will count how many sit-ups the child performs in 1 minute.

k. Examiner will terminate test at 1 minute with the word “stop” and record the number of sit-ups performed.

l. 5-minute rest will be given.

7. Flexicurve Measurement

a. "Will you now please stand how you normally would with your back toward me in front of this table, while I get another curve measurement of your low back."

b. "I'm now going to lift up the back of your shirt and ask you to pull your shorts down just enough so that we can see your low back. We will now need to feel your back to find the landmarks for our measurement."

c. "If you feel like you are going to lose your balance while I am getting your curve measurement, feel free to hold onto the table in front of you."

d. Place the flexicurve so the top of the instrument is at L-1 and the end of the instrument is at S2, mold the flexicurve accordingly.
e. "We are now finished with this portion of the test. Please wait just a minute while we trace the mold of your back on a piece of paper and then we will move on to the abdominal tests."

f. Examiner will trace the molded flexicurve on a piece of paper and label it with the participant's identification number.

g. Subjects will be dismissed from the study and given a piece of candy.
APPENDIX H

Data Collection Sheet

School: _____________________________________________

Age: _______ Sex: _______ Subject#: ______________________

Pilot subject: Y/N

Prescreen:

Posterior pelvic tilt achieved: Y/N

90°/90° Straight Leg Raising Test: Y/N

Thomas Test: Y/N

Ability to follow instructions: Y/N

Procedure:

Pre-testing Flexicurve measurement: __________________________

Kendall's Upper Abdominal test: Normal (1) Good (2) Fair+ (3)

                        Fair (4)

Kendall's Lower Abdominal test: Normal (1) Good+ (2) Good (3)

                        Good- (4) Fair+ (5) Fair (6)

Presidential Physical Fitness Abdominal test score: ________________

Post-testing Flexicurve measurement: ______________________________
APPENDIX I

Presidential Physical Fitness Test

Instructions for the Presidential Physical Fitness Award Test

CURL-UPS (Boys and Girls)

OBJECTIVE—Number of curl-ups performed in one minute.

EQUIPMENT—Stopwatch. A mat or other clean surface is preferred.

STARTING POSITION—Student lies on back with knees flexed at 90 degrees; partner holds feet. Heels should not be more than 12 inches from the buttocks and the back flat on the floor. Arms are crossed with hands placed on opposite shoulders, arms close to chest. The arms are held in contact with the chest at all times.

ACTION—Student raises the trunk curling up to touch elbows to thighs and then lowers the back to the floor so that the scapulas (upper back) touch the floor. This constitutes one curl-up.

THE TEST—The timer calls out the signal "GO" and begins timing one minute. Student stops on the word "stop." The number of correctly executed curl-ups completed in 60 seconds is the student's score.

RULES—
1. "Bouncing" off the floor/mat is not allowed.
2. The curl-up will be counted only if the student (a) keeps fingers touching shoulders; (b) touches elbows to thighs; and (c) returns to position with scapula touching floor before curling up again.
# Qualifying Standards

## The Presidential Physical Fitness Award

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## The National Physical Fitness Award

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## The Participant Physical Fitness Award

Boys and girls who attempt all five items, but whose scores fall below the 50th percentile on one or more of them are eligible to receive the Participant Award.
Figure 2. Drawing to depict length (L) and height (H) of curve used to calculate theta. A corresponds to the L1 spinous process; B corresponds to S2 spinous process.