

**A Comparison of the Effect of Trunk Stability and Trunk Movement Strengthening
on Vertical Take-off Velocity**

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By

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Abstract

A Comparison of the Effect of Trunk Stability and Trunk Movement Strengthening on Vertical Take-off Velocity

The purpose of this study was to determine if the type of training (trunk stability exercise versus trunk movement exercise) influenced vertical jump differently. The study also examined two secondary questions: the influence of trunk stability training versus trunk movement strengthening on abdominal muscle hypertrophy and the influence of trunk stability training versus trunk movement strengthening on trunk stability endurance. The study examined the relationship between the main dependent variable (vertical take-off velocity), and the 2 sub analyses (abdominal muscle thickness and trunk stability endurance).

Fifty-nine adults from a normal population were randomly assigned to a control group, a stability training group, and a movement training group. After 12 weeks, 46 participants' data were utilized in the statistical analysis of vertical take-off velocities. Testing of vertical jump, leg press strength, abdominal thickness measures, trunk stability strength and trunk stability endurance occurred at week 0 (baseline), after the third and after the twelfth week of training.

Using a repeated measures ANCOVA, it was determined that neither the stability nor the movement group changed their vertical take-off velocity after 12 weeks of training. Both the stability and movement groups' trunk stability endurance scores were significantly greater from the control group's scores at week 12 ($p < 0.05$). Rectus abdominis thicknesses in the movement group increased significantly at week 3 and again at week 12, but there was no significant difference from the control or stability groups at

these times. Because the rectus abdominis was significantly smaller in the movement group versus the stability group at week 0, this may account in part for the fact that it showed significant increases in the movement group. For transversus abdominis, there were no significant changes overall between weeks 0 and 12 in any of the groups over time. These findings indicate that although rectus abdominis muscle thickness can be increased by training movement exercises, and trunk stability endurance can be changed by training movement or stability exercises for the trunk, these changes do not result in changes in the performance of vertical jump.

Acknowledgments

There are many people that I want to recognize for their generous time and help during the past two years. Bruce Craven has been an incredible teacher and a respected friend. He initially interested me in the topic of trunk stability during my undergraduate physical therapy work, and his influence has stayed with me through my years as a clinician and now as a graduate student. His organization and patience over the past two years will always be appreciated. He has an amazing ability to see “the bigger picture” and to keep his students focused on their goals. Also, I want to thank Dr. Eric Sprigings for his kindness, diligence in striving for perfection, patience in achieving the best outcomes, and for his tutelage in biomechanics. I want to thank Dr. Phil Chilibeck and Dr. Kevin Spink for their ideas and assistance on my committee. All of the professors at the College of Kinesiology under whom I have studied have made tremendous contributions to my understanding of literature and research. I also want to recognize and thank my research participants as well as numerous friends who volunteered their time during the data collection.

I want to thank my father for encouraging me to study, my mother for believing I could do anything, and my siblings for their support throughout my studies. I also want to thank my husband, Roger Grona, for his pride in my efforts, and for his endless participation. He assisted with every aspect of my data collection (even at 11 pm and 2 days before our wedding), pushed me through some difficult days in the lab and on the computer, posed for all of my participant exercise photos, and managed all of these feats without a single complaint.

Dedication

This thesis is dedicated to my mother, Linda Diane Lovo, who passed away April 23, 1997. My mom was a teacher, well known for the effect she had on each and every student she taught over 25 years. She loved education and knowledge, and passed the love on to her children. From the time I was a young girl, she always encouraged me to do all I could to increase my knowledge and learn from any situation that I could. I have thought of her and missed her through every component of my graduate work. I have realized that because of her many sacrifices as a parent, I have had more opportunity for learning than the majority of people in this world. I will never forget her tears at my undergraduate convocation. I think she would have been proud to see me complete my thesis.

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Glossary of Terms

Closed kinetic chain = Generally, closed kinetic chain refers to a movement in which the end of the moving limb is in contact with the ground. Specific references (from the literature) in the text of this thesis are accompanied by the specific exercise selected by individual researchers to clarify the use of the term.

Countermovement jump = A countermovement jump begins in standing, follows with a downward movement and finally a push-off (Bobbert et al., 1996).

Endurance = In the context of this study, the term endurance is utilized to describe the ability to sustain a contraction over a period of time. It is not being used to describe an aerobic ability, nor is it being used in the sense of the aerobic energy system. The term endurance is utilized in the literature by McGill (2001) to describe what is actually the sustainability of a stable lumbar spine, and due to the fact that this is a new concept in the literature, the term used by McGill will be used in this thesis.

Extension moment = A moment is a turning effect of a force applied at a certain point (Nigg et al., 2000). In the lumbar spine, when the moment is one of extension, the result is movement of the lumbar spine into extension (back).

Hypertrophy = Hypertrophy is an increase in the size of a muscle cell (Hoeger and Hoeger, 2002).

Intra-abdominal pressure = Co-contraction of abdominals, the diaphragm and the pubococcygeal muscles create intra-abdominal pressure. This results in the trunk behaving as a dense cylinder, enabling more effective distribution of compressive and shear forces within the trunk (Norris, 1995c). At the same time as this pressure is increasing, the transversus abdominis muscle (which contributes to the pressure) places

tension on the thoracolumbar fascia (Norris, 1995c). Norris (1995c) indicated that intra-abdominal pressure produces a moment of extension on the spine. This is really due to the fact that the thoracolumbar fascia is behind the spine, causing the extension moment.

Kinetics = Fleisig et al. (2000) define kinetics as the forces and torques causing motions.

Open kinetic chain = Generally, open kinetic chain refers to a movement in which the end of the moving limb is not in contact with the ground. Specific references (from the literature) in the text of this thesis are accompanied by the specific exercise selected by individual researchers to clarify the use of the term.

Plyometric = Plyometrics is incorporation of speed and strength training with explosive jump training (Hoeger and Hoeger, 2002).

Strength = Tittel and Wutscherk (1992) defined strength as the basis for movement, specifically the contractility of muscle fibers. They described that strength is determined by neural activation, and involves a muscle's ability to develop force.

Tonic muscle activity = This term refers to continuous muscular contraction (Pearsall, 2001).

Trunk stability endurance = This term describes a test of the ability to sustain a co-contraction of the abdominals (while maintaining a neutral lumbar spine) for as long as possible (see section 2.3.2.3 for complete details), while maintaining specific testing criteria.

Trunk stability strength = This term describes a test of maximal double leg lowering ability (see section 2.3.2.2 for complete details). It refers to the ability to maintain the lumbar spine within the limits described in section 2.3.2.2 while lowering the legs. The objective is lower the legs as far as possible while maintaining the required position.

Chapter 1 – Scientific Framework

1.1 Introduction

Panjabi (1992) initially defined three interconnected systems of spinal stability. The active system is made of the muscles. The passive system is the non-contractile tissues, and the nervous system is responsible for controlling the first two systems. The active and neural control systems have been the focus of recent research.

Different research groups have defined spinal stability. One definition that has frequently been referenced in the literature for stability is stiffness of the spine and surrounding musculature (Jull and Richardson, 2000, O'Sullivan et al., 1998). Other authors have described stability as motor control required to prevent unwanted movement (Hodges and Richardson, 1998, Richardson et al., 2002). Some authors have referred to the activity in the trunk to define stability, for example, Norris (1995a) referred to stability as isometric co-contractions of trunk muscles.

It has been generally agreed that stability training involves re-education of the stability muscles, training static spinal control while increasing load, training dynamic spinal control, and finally focusing on functional training or sport-specific training (Norris, 1995e). Although all of the research on spinal stability has agreed that the abdominal muscles play a role in stability, no research has examined whether stability training affects the structural property of muscle size of the abdominals. As well, controversy exists as to whether the abdominals perform an endurance function in their role as stabilizers. Some research has highlighted the likely importance of trunk stability in function or sport measures (Norris, 1995, Richardson et al., 1990, McGill, 2001). Despite this indication of importance to function, no published literature has examined the effect of training for stability on a functional outcome measure. Stability exercises

continue to be used in athletic training programs, and yet no research has examined their usefulness in such settings.

Vertical jump has been studied for many years. The majority of the research has focused on training legs with strength, power and plyometric programs. Very few researchers have mentioned the role of the trunk in the vertical jump. No one has examined what effect increasing hypertrophy (strength) and endurance of trunk muscles might have on the vertical jump.

Control and coordination are two of the terms used in definitions of stability. These characteristics have been identified by many research groups as critical to vertical jump performance (Dowling and Vamos, 1993, Kraemer and Newton, 1994, Bobbert and Van Soest, 1994). In this study, the effectiveness of training trunk stability versus training trunk movement strengthening on a vertical jump will be investigated. As well, the effect of training trunk stability versus trunk movement strengthening on hypertrophy of abdominal muscles and on trunk stability endurance will be examined.

1.2 Literature Review

1.2.1 Trunk Stability Definitions

Trunk stability has been defined by Norris (1995a) as isometric co-contraction of the trunk muscles during function. He described that some muscles produce large trunk movements, and others work to fixate or stabilize the spine. This spinal stability controlled for unwanted movement. He described one of the functions of trunk stability as the ability to involuntarily synchronize optimal trunk activity. This synchronization occurs because of neural system control. McGill (1998) described that strengthening of back and abdominal muscles is not just important for preventative and treatment

programming, but is an important part of any general fitness programming. He emphasized that co - contraction of muscles results in stability. He identified that muscles involved in core trunk stability include the external oblique, internal oblique, transversus abdominis, and quadratus lumborum. Richardson et al. (2002) defined stability as mechanical control of a joint. They specified that stability involved the muscles that controlled unwanted movement and prevented injuries to the surrounding ligaments and joint capsules.

Three stability systems were identified by Panjabi (1992a, b). Muscles formed the first system, known as the active system. The second system, or passive system, arose from the non-contractile parts (ligaments, joint capsule, discs and vertebrae). The third system was the nervous system. These three systems adjusted for each other in a dynamic interaction (Figure 1.1). Panjabi hypothesized that spinal stability was a requirement for load-bearing and movement transfer between different body segments. Panjabi (1992b) also described the neutral zone of the spine, or the flexible area between the extremes of motion. Within this zone, the least work was required to produce movement. Panjabi's systems have been cited by other authors. Norris (1995b) described that the systems were interconnected by proprioception, which Oxford's dictionary (2001) defined as "stimuli relating to position and movement of the body (pp.1147)." Proprioception would require the active, passive and neural systems to work together. Norris (1995b) reported that lack of use of the systems could result in a deficit of the neural control system (system three). Lee (1999) referred to Panjabi's (1992a) work, stating that in the mid range (neutral zone), if the stability muscles were weak, the neutral zone would be expanded (Figure 1.2). In further examination of Panjabi's work

(1992a, b) it was apparent that he cited muscle tension as important to stability, but he did not conclude that strength was the specific requirement. He reported disuse as a factor that could cause deterioration of the active system. He referred to muscle strengthening benefits for people with ligament injuries of the knees, and hypothesized that based on research with the knee, muscle strengthening *may* assist the passive system in the spine. He hypothesized that an improved ability to create muscle tension could lead to greater spinal stability. He did not conclude or investigate, however, if this was the case. Gibbons and Comerford (2001) found that the passive system functioned at the extremes of range (not in the middle) and that the active system was responsible for controlling excessive motion in mid range.

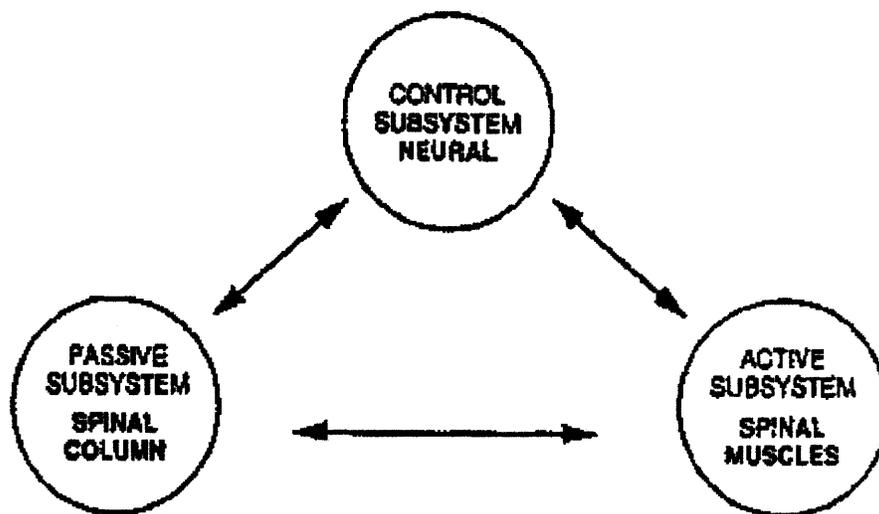


Figure 1.1 Three subsystems (Panjabi, 1992a)

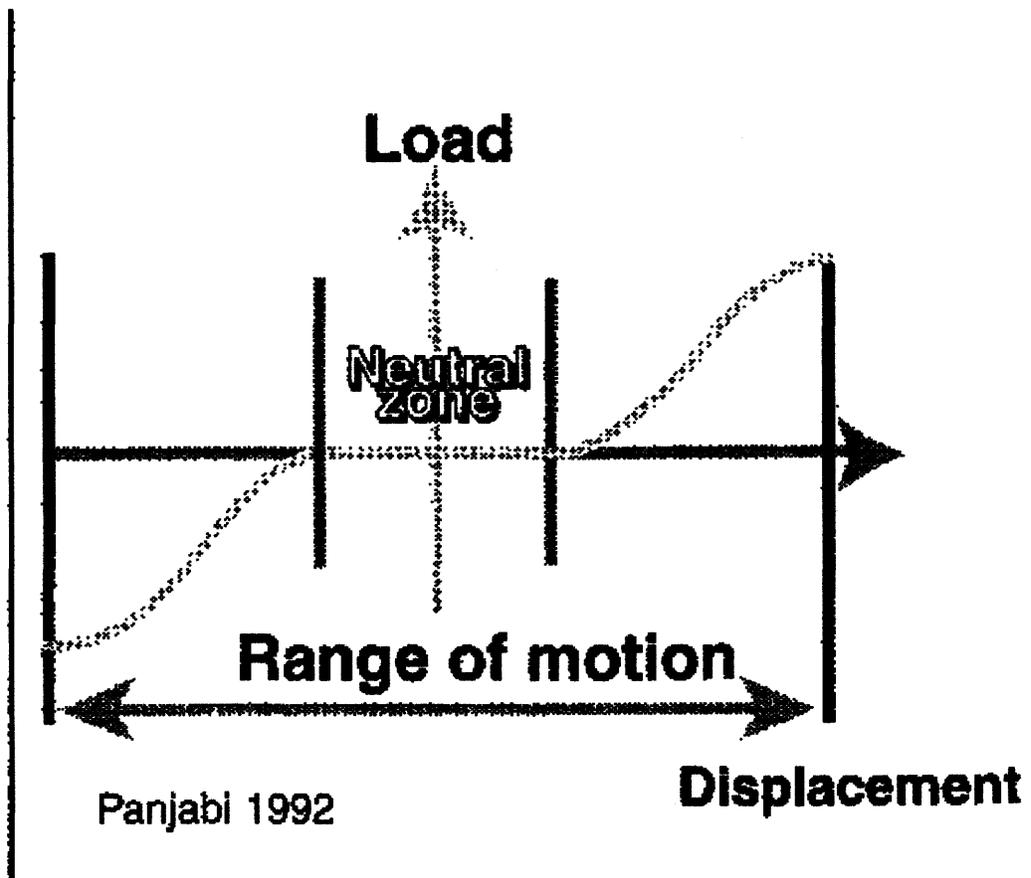


Figure 1.2 Mid-range of motion from Lee, 1999 (Panjabi, 1992a)

Stiffness is a term used in the literature to describe generic stability. Jull and Richardson (2000) were more specific to explain that the local muscle system (stabilizers of the spine) is in close proximity to the vertebrae. This enables the muscles to stiffen around the spine. Richardson et al. (1999) reported that co-contraction of deep abdominal muscles would create stiffening, but not movement, of the lumbar spine. O'Sullivan et al. (1998) also reviewed the effects of the abdominal obliques and transversus abdominus in providing stiffness to the lumbar spine. They conducted a study examining differences in recruitment of deep abdominals and rectus abdominis. For

people suffering from chronic lumbar pain, they concluded that deep abdominals could be trained in isolation. The group that performed the deep abdominal exercises demonstrated a significant increase in activation of unilateral internal oblique during a double leg raise maneuver. This increased activity of internal oblique should enhance lumbar stiffness. They demonstrated the impact of exercise specificity and highlighted the possibility of specific exercise affecting patterns of recruitment or synergy in the trunk. A weakness of study design was inherent in the study. The authors utilized the abdominal hollowing maneuver to achieve co-contraction of deep abdominals, but modified it slightly to involve flattening of the lumbar spine or a posterior pelvic tilt. If the participant is attempting to move or flatten the spine during the maneuver, then it could be argued that the spine is not stable, and that internal oblique could be functioning in a movement capacity. This could have been easily controlled for by allowing no movement during the co-contraction. It must be noted here that a majority of the spinal stability research has been performed on populations with lumbar pain. The results are being reviewed to demonstrate the progression of research in the area of spinal stability, but some limitations may be inherent when applying the principles to a normal (pain free) population, as not as much research has examined the normal population.

Gibbons and Comerford (2001) indicated that muscle stiffness can result from hypertrophy (due to a greater density of fibers), or from motor control adjusting muscle tension according to the body's needs. They explained that motor control is adaptable to function. I did not find evidence from this article, however, of whether hypertrophy and motor control are important in spinal stability.

Sahrmann (2002) defined stiffness as resistance during passive lengthening of muscle and connective tissue. She reported that muscle is the major contributor to stiffness. She postulated that during movement, joint motion would be less when the joint is stiff. So it would seem apparent that there must be stiffening of the spine by the muscles, yet movement must also occur by the muscles. Movement is a common function associated with muscles. What we do not know from this is what aspect or property of muscle is contributing to the stiffness.

McGill (2001) described that for optimal performance, a spine must be stable before moments and forces occur. He reported that Crisco and Panjabi's (1992), and Crisco et al.'s (1992) research on lumbar spines (with ligament structures intact) outside the body revealed buckling of the spine when twenty pounds of (compressive axial) force was applied. McGill surmised that this was evidence of the stiffening effect of muscles in the human spine that prevented buckling in everyday circumstances. He contended that due to the number of joints and planes of movement in the lumbar spine, one muscle failing to generate adequate stiffness can result in an unstable situation.

Lee (1999) summarized three of the components that are integral to stability. The first was tonic, sustained muscle contraction. The second was adequate coordination to control the amount of movement in mid range. The third was motor control enabling smooth, efficient motion.

In summary, several definitions are used in the literature to describe trunk stability. Isometric co-contraction, fixation, involuntary synchronization, mechanical joint control, and stiffness of muscles have all been reviewed here. More importantly, we have seen that in order to clearly define trunk stability, we must consider all components:

passive, active and neural (Panjabi, 1992a). We can see that these are all related terms. However, what we do not find clear in the current definitions of trunk stability is the physiological property or properties of muscle that contributes to creation of stiffness, fixation, and synchronization. As well, many of the authors have emphasized that stability is critical to dynamic function. We do not find clarification, however, on how stability functions during movement.

1.2.2 Stability Mechanisms

There are numerous philosophies and models for the mechanisms involved in trunk stability. Norris (1995c) reviewed four major theories:

1. Intra-abdominal pressure mechanism: He described that pressure in the abdomen produced an extension moment on the spine. The abdominals, diaphragm, and pubococcygeal muscles must contract together for optimal intra-abdominal pressure. Transversus abdominis, more than the oblique abdominals, has a positive effect on intra-abdominal pressure. This pressure creates a dense cylinder out of the trunk, enabling more effective distribution of compressive and shear forces within the trunk. Evans and Oldreive (2000) agreed that because transversus abdominis is oriented in a circumferential manner, it is easy for transversus abdominis to contribute to intra-abdominal pressure. Norris (1995c) reported that sit-ups do not increase intra-abdominal pressure and do not involve the coordination necessary for intra-abdominal pressure generation. Norris (1995 e) reported that rectus abdominis and external oblique lateral fibers are more important in movement than stability.

2. Posterior ligaments: Ligaments stiffen (thereby increasing tension) when put on a stretch. This prevents excessive movement, thereby increasing trunk stability, at the extremes of range.
3. Thoracolumbar fascia (Figure 1.3): Transversus abdominis attaches to this fascia and when it contracts there is tension imposed on the thoracolumbar fascia. Also, there is a layer of the fascia that wraps around the erector spinae and when these muscles contract, they press against the fascia and increase the tension. Increased tension, or stiffness, in the thoracolumbar fascia increases trunk stability. Pool-Goudzwaard et al. (1998) indicated that the internal oblique also attaches to this fascia. They added that the thoracolumbar fascia also increases stability of the sacroiliac joints.

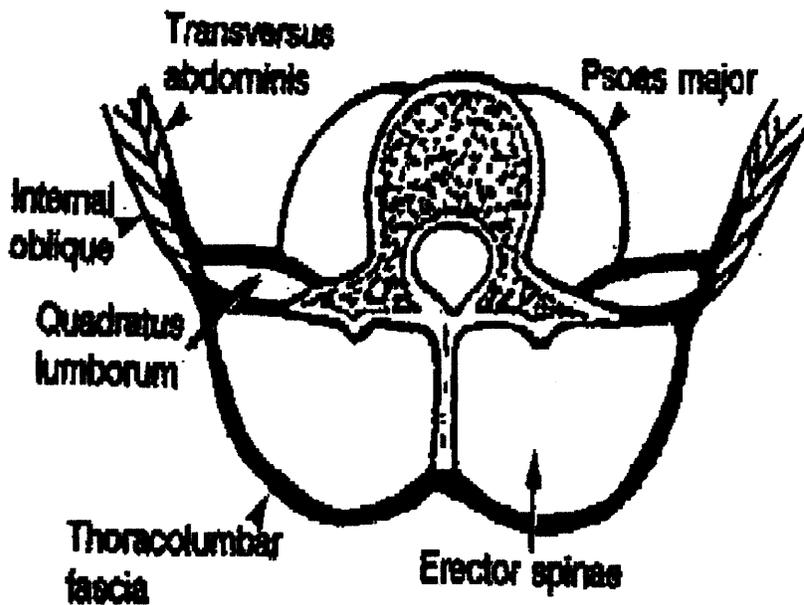


Figure 1.3 Thoracolumbar Fascia Attachments (Norris, 1995c): The erector spinae and thoracolumbar fascia represent the posterior aspect of the diagram. The psoas major is the anterior aspect.

4. Muscles: Intersegmental spinal muscles control movements at each spinal segment.

As well, transversus abdominis and internal oblique are considered to be stabilizers.

Norris reported that transversus abdominis is most important in intra-abdominal pressure changes.

Hodges and Richardson (1996) researched the role of transversus abdominis motor control in trunk stability. They examined its reaction to shoulder movements in people with and without lumbar pain. They found that transversus abdominis was always the first muscle to activate in the painless group, regardless of what direction the arm eventually moved. Transversus abdominis was always active before the shoulder muscle. They also identified a motor control deficit in transversus abdominis in people with lumbar pain. There was a loss of the stabilizing mechanism of transversus abdominis because the muscle was never activated before the shoulder muscles were activated. The authors felt that this novel finding indicated central nervous system control of trunk response to arm motion. They explained that when the transversus abdominis contracted, intra-abdominal pressure increased and the lumbar spine stiffened accordingly. They determined that the stiffening of the spine before arm movement would control for unwanted motion between spinal segments (that would normally occur due to forces on the spine). Hodges and Richardson (1997b) identified that when speed of movement was varied, transversus abdominis activated before the shoulder muscles only for fast movement. However, they did not find a significant difference between the fast and natural speeds. They concluded that anticipatory contraction of the abdominals accompanied normal functional movement and was not restricted to fast limb movements (Hodges and Richardson, 1997b). For slow movement, activity of all abdominal muscles

was delayed. The weakness inherent in this study was the definition of anticipatory contraction, which is an important concept in transversus abdominis as a stability mechanism. They defined transversus abdominis activation within 50 ms of the shoulder muscle as anticipatory. They failed to explain how they arrived at this definition. A second weakness was that although many sporting skills including the vertical jump occur at fast speeds, shoulder flexion does not constitute a functional movement pattern of any sporting activities when performed in isolation. This limited the applicability of their study to the present experiment.

Hodges and Richardson (1997 a) also studied abdominal activity and leg movement in people without pain. Again, transversus abdominis always reacted before the leg muscle doing the actual movement. They found that the direction of leg movement didn't alter the activation of transversus abdominis or the obliques (internal oblique and external oblique). This was the first indication that external oblique might contribute to trunk stability. In 1998, Hodges and Richardson examined these responses in a population with lumbar pain. A motor control problem was identified because transversus abdominis activity was impeded in every direction that the hip moved. Both the arm and leg movement studies by Hodges and Richardson indicated that during movement in normal populations, a feed-forward postural response was present (Hodges and Richardson, 1998). Hodges and Richardson (1998) postulated that this could be a motor control stability mechanism. They were careful, however, to highlight that these movements were not functional. Hodges and Richardson summarized their findings in a 1999 article by reporting that the anticipatory contraction braced the spine for any forces that would be imposed on it during movement. Richardson et al. (2002) determined that

transversus abdominis activation decreased sacroiliac joint laxity more than a total abdominal bracing motion.

McGill and Cholewicki (2001) discussed energy to explain the biomechanics behind trunk stability. Nigg et al. (2000) defined potential energy as the energy due to the position of a mass. McGill and Cholewicki (2001) described:

$$\text{potential energy} = \text{mass} * \text{gravitational acceleration} * \text{height}$$

McGill and Cholewicki (2001) used an analogy of a ball in a bowl. The least potential energy is when the ball is sitting at rest in the bottom of the bowl. This system is only stable if the ball stays there and is not disturbed. McGill and Cholewicki (2001) imagined a bowl with 36 degrees of freedom. The number 36 came from six joints in the lumbar spine, with six possible directions of movement at each joint. All of the components of stability (passive, active and motor control aspects) had functions of protecting the height of the bowl for each degree of freedom (Figure 1.4).

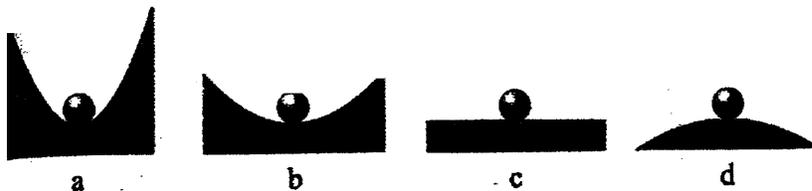


Figure 1.4 Analogy of Ball in a Bowl, demonstrating a more stable (a) to a less stable position (d) (McGill and Cholewicki, 2001)

Also, McGill and Cholewicki, (2001) reported that potential energy is also a consideration with stiffness and storage of elastic energy in muscles. They used the term elastic potential energy and reported the following relationship (strain energy is being

substituted for potential energy in their formula for clarification, due to the fact that this formula is the known calculation for strain energy):

$$\text{Strain energy} = \frac{1}{2} * \text{stiffness} * (\text{distance the tissue is stretched})^2.$$

McGill and Cholewicki (2001) reported that as stiffness increased, the height of the sides of the bowl increased, thereby increasing stability in the muscular system. A motor control problem would affect the dynamic interaction of the three stability systems, and one of the bowl's walls or degrees of freedom would be unprotected. Unwanted movement could then occur.

In summary, the chart below reviews some current literature trends in explaining stability. The different authors listed agree that both intrinsic muscle properties and neural properties (control) are involved.

Panjabi (1992 a, b)	Lee (1999)	Norris (1995c)
1. active subsystem	1. tonic contraction	1. intra-abdominal pressure mechanism
2. passive subsystem	2. muscle coordination	2. ligaments
3. neural control subsystem	3. motor control	3. thoracolumbar fascia
		4. muscle control

The literature definitions and mechanisms behind stability are lacking in two aspects. First, there is no agreement as to the physiologic or intrinsic muscle properties required to enhance trunk stability. Second, no one has studied stability in relation to function. If we do not know how stability relates to functional movement, for example, athletic skills, then we can not determine its complete usefulness as a prescribed form of exercise.

1.2.3 Stability Training

Richardson and Jull (1995) cited McArdle et al. (1991) who reported that 30-40% maximal voluntary contraction was needed to train tonic muscle control. Norris (1995 d) explained that stability training involves 20-30% maximum voluntary contraction isometrics (he did not identify his source), that are held 10 seconds and then performed repetitively. McGill and Cholewicki (2001) reported that 10% of maximum contraction was enough for stability. This was based in part on their prior research (Cholewicki and McGill, 1996). Despite the controversy, it is agreed in theory that the ideal contractions are sub maximal. Richardson and Jull (1995) explained the reasoning for sub maximal contractions. They reported that because tonic motor units are primarily involved in stabilizing joints, and these units are at risk of poor function if disuse occurs, a prolonged constant hold at low maximal voluntary contraction would be recommended for training. It must be noted that Richardson and Jull (1995), Norris (1995 d) and McGill and Cholewicki (2001) are referring to training in situations of pathology (injury, pain). There may be limitations in applying the theory to a normal population.

Norris (1995 e) described four components of stability training:

1. re-education
2. static control of the spine and pelvis while increasing load
3. dynamic control of the pelvis or control throughout range
4. functional training (joint angle specific changes or task-related practice) (Norris 1995 e).

Jull and Richardson (2000) explained that with dysfunctional stabilizers, the contractions must be cognitive or purposeful, and separate from the larger, more superficial muscles. The goal in training is automatic recruitment of the stabilizers.

In summary, there is agreement that sub maximal contractions are sufficient in training trunk stability. Despite the recommendation for functional training, however, there is a lack of evidence in the literature on whether training stabilizing musculature will have an impact on improving functional outcomes or athletic skills.

1.2.4 Vertical Jump

A review of the research on vertical jump will be included in this section since it has been shown that many variables can affect the outcome performance. Research has included investigation on the involvement of different body parts, recommendations for optimal training, as well as the involvement of control/coordination and work output to vertical jump performance. The progression of the past research and theories in the area of vertical jump will assist the understanding of the problem and hypothesis related to vertical jump in this thesis.

Luhtanen and Komi (1978) discussed the role of the entire body in vertical jump. They determined that take-off velocity (of a squat jump), was decided by a unique combination of body movements. They felt 56% (of take-off velocity) came from knee extension, 22% from plantar flexion, 10% from trunk extension, 10% from arms and 2% from the head. Take-off velocities were only 76% of the predicted maximum. The authors felt that coordination of these parts was important for maximizing the take-off. Tant et al. (1993) identified that trunk flexors act in an isometric capacity during the

airborne phase. To the present author's knowledge, other research has not addressed the function of the trunk flexors during jumping.

Hubley and Wells (1983) found that three muscle groups were the major contributors to vertical jump take-off: hip extensors, knee extensors and plantarflexors. They reported that the mean ratio of energy generated to work done was $0.997(\pm 0.07)$ for the countermovement jump. This proves a very efficient use of energy. Robertson and Fleming (1987) determined the hip, knee and ankle extensors (plantar flexors) act at the same time to produce leg extension.

Hakkinen and Komi (1985) examined explosive training (variations of jumping) on vertical jump by using a force platform and EMG. They found increases in the high velocity aspects of the force-velocity curve, attributing these to neural changes. They did not attribute these to mere strength gains, as these were minimal.

Ball et al. (1992) determined that in boys ages 7-11, lean body mass was positively related to vertical jump as were age, height, and leg length. Static strength in the thigh, leg and calf muscles was not correlated with vertical jump ability. They postulated this lack of correlation may have been related to lack of coordination in the children, or else a lack of importance of these muscle groups to jumping, which seems unlikely to the present author, based on the fact that these muscles are responsible for generating force for take-off. All leg extensors were tested (thigh and knee extensors, and plantar flexors), and it would not seem plausible that strength in these massive muscle groups would not contribute to the vertical jump. Sum of skin folds was negatively correlated with vertical jump ability. Ball et al. (1992) explained that more body fat was associated with worse performance. Trunk motion and control were not

factored into the study at all. Miller et al. (2002) also found that more body fat had a negative correlation with vertical jump ability in male university football players.

Dowling and Vamos (1993) calculated jump height using the formula:

$$\text{Height} = (\text{vertical velocity at takeoff})^2 / (2 \times \text{gravitational constant})$$

The best single predictor of jump height was maximum positive power and the authors felt that strength training should be targeted at high velocity. Their findings agree with the later reports by Bobbert et al. (1996) that greater height resulted from greater work output in take-off. They found that training to enhance vertical jump should involve power, coordination and rate of force development. The weakness of this study was described by the authors as the inability to identify the reasons for poor power in jumping. And without an analysis of the many body parts involved, it was impossible to see if a specific component might have been at fault.

Kraemer and Newton (1994) reported that take-off velocity determines VJ height.

They identified four key points regarding the vertical jump:

- Muscle force, speed and neural coordination determine the result of a jump.
- The stretch-shortening cycle involves storage of elastic energy in muscles that are on a stretch to assist in the establishment of the jump's power.
- Specific training for jumping is necessary to optimize coordination.
- Different training methods have improved vertical jump, including strength, explosive training and plyometrics.

Kraemer and Newton (1994) also stated their opinion that power is a key in vertical jump as power involves the fast output of force. Kraemer and Newton (1994) discussed appropriate periodization of training for vertical jump. They reported that preparatory

activities should focus on muscle hypertrophy and strength, progressing to explosive performance of concentric components. Following this, neural optimization should be emphasized using plyometric exercise. They reported that the stretch-shorten cycle should be optimized by loading muscles on a stretch to maximize stored energy. We will see that later research will disprove the stretch-shortening cycle as critical to the establishment of a jump's power. Finally, they emphasized that training programs should be specific to jumping skills.

Bobbert and Van Soest (1994) examined strength and control during jumping. They determined with schematic models that increasing strength without increasing control would cause maximal jump heights to actually worsen. They described that poor control resulted in early take-off, and therefore inability for all involved muscle groups to produce maximal work for the jump. The best situation identified was when strength and control were both maximized; then VJ was at its best. They advocated practice of jumping as an integral part of improving vertical jump.

Bobbert et al. (1996) explained the countermovement jump as a jump that begins in standing, follows with a downward movement and finally a push-off. They postulated that coordination was important in performing a maximal jump and that poor control would likely affect the movement pattern, causing the amount of muscle work that gets transferred to energy (contributing to jump height) to be less than maximal. Dowling and Vamos' (1993) graphical representation of the countermovement jump assists in the understanding of the biomechanics of a countermovement jump (Figure 1.5).

Bobbert et al. (1996) also observed that a countermovement jump results in a higher jump than a squat jump (where the starting position is a squat, so there is no period

of dropping down from the erect position described above). In examining how the work output was optimized in the countermovement jump, however, the authors did not think coordination was the total answer. The authors described that the countermovement elicited greater joint moments at the beginning of push-off, which resulted in greater work output. They determined that stored elastic energy is not the reason for greater power output as thought earlier by researchers. Rather, greater moments available contribute to greater power. Using models, they deduced that the stored elastic energy did not add to the total work for push-off, it just added to the efficiency of doing the work. To summarize, the countermovement enabled activity and force generation in the muscles prior to push-off so more work could be produced.

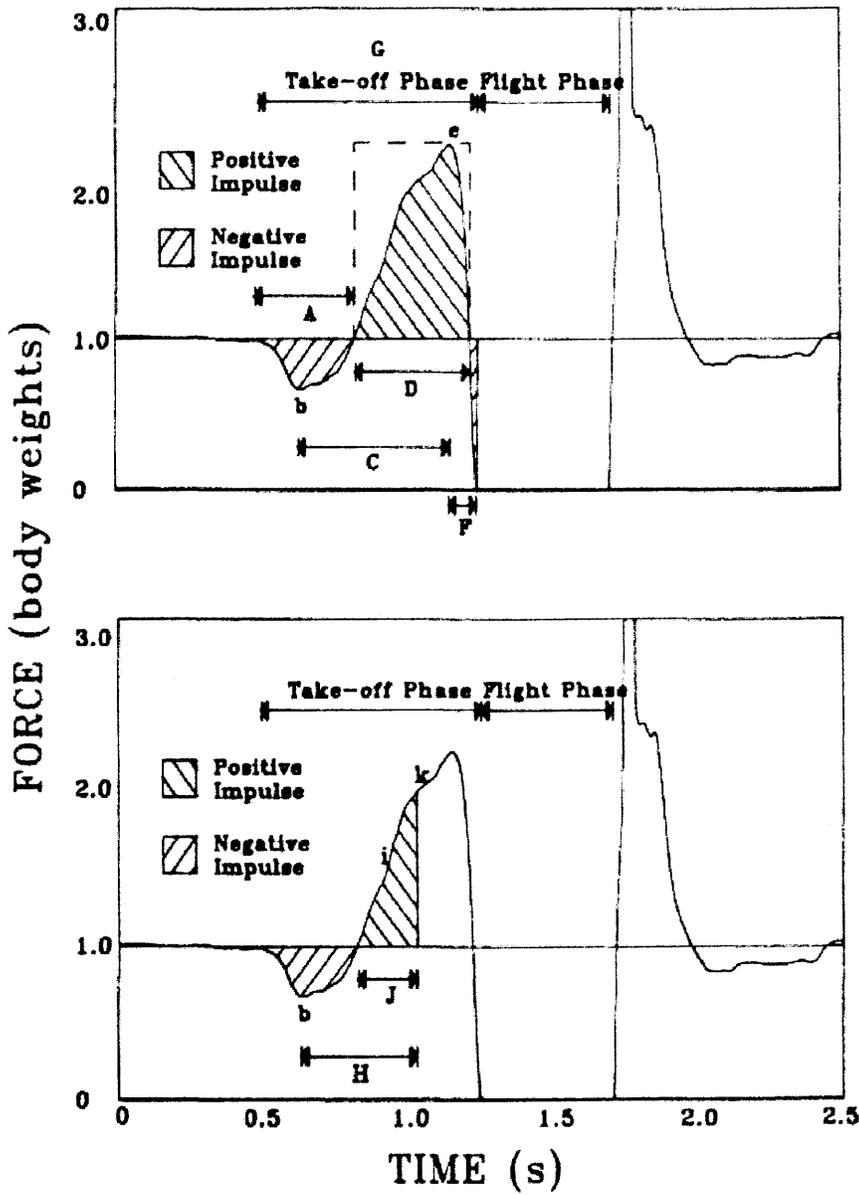


Figure 1 — Temporal and kinetic variables measured from the force-time curves of the vertical jumps. A = duration of major negative impulse; b = minimum force; C = duration from minimum to maximum force; D = duration of major positive impulse; e = maximum force; F = duration from maximum force to takeoff; G = duration of takeoff phase; H = duration from minimum force to low point; i = maximum positive slope of force; J = duration from maximum negative velocity to low point; k = force at low point.

Figure 1.5 Variables in a Countermovement Jump (Dowling and Vamos, 1993)

Authors have examined differing training methods to improve the vertical jump. Blackburn and Morrisey (1998) examined open (knee extension) versus closed (squat) kinetic chain strength and its influence on vertical jump. The arms were immobilized during jump testing to control their effect on the jump. They found that closed kinetic chain strength significantly correlated to vertical jump ability, while open kinetic chain strength and vertical jump ability did not correlate significantly. Augustsson et al. (1998) determined that closed kinetic chain (squat) training improved vertical jump ability while open kinetic chain (knee extension and hip adduction on machines) exercises did not.

Many authors have examined the influence of the arms on jump height. Feltner et al. (1999) found that arm swing resulted in greater take-off velocity and vertical jump height. In summary, it is important in any vertical jump protocol to control for the arms' contribution to the jump.

Le Pellec and Maton (2002) discussed a novel idea related to vertical jump called anticipatory postural adjustments. They describe that the central nervous system functioned to predict for positional and balance changes. They described that in a vertical jump, an initial backward shift of pressure results in a loss of balance at the onset of movement. This shift then switches direction and continues forward. As the shift forward occurs, the body's center of gravity is accelerating (in the vertical plane). These two occurrences were correlated at $r = 0.885$. The authors felt that the design of the shift contributed to jump height. They also commented that forward movements had to undergo a braking mechanism of some kind (otherwise the body would move too far forward and the jump would not be optimal). They attributed this braking task to certain

leg muscles. They failed to examine any effect that the trunk muscles may have on such a function.

Nagano and Gerritsen (2001) suggested two methods to improve vertical jump were via the neuromuscular system and coordination. They determined that muscle hypertrophy and therefore strength (in the leg muscles in their study) was the most important determinant in improving vertical jump. They reported that it may be possible to enhance jumping even more by coordinating muscle groups to optimize the neuromuscular system. Although their study was about the muscles in the legs, the principles of enhancing jump with coordination could easily be applied to the muscles in the trunk.

In summary, the literature identifies muscle power, control/coordination and training specificity as important to the outcome of a vertical jump. The majority of the recent research has focused on the legs. As we have previously seen, research on trunk stability reports neural control and coordination of the passive, active and neural stability subsystems (Panjabi, 1992a) as major players in trunk stability. There could be a component of vertical jump that has so far been uninvestigated in the published literature; namely, trunk stability as it contributes to the power or control, and therefore the outcome of a vertical jump. Also, does the endurance (ability to sustain a contraction over a period of time) of the trunk affect vertical jump through control of the trunk? As well, we cannot find in the literature any evidence of studies of training the trunk and the effect this may have on vertical jump. The present study will attempt to examine these areas.

1.2.5 Trunk Stability and Endurance

Muscle groups can be trained for endurance by using repetition of exercise or by holding a single contraction for a long period of time. Variation exists in the literature as to whether endurance plays a role in trunk stability, or if motor control is the most important component. Literature to date has examined both endurance and motor control as important factors in trunk stability.

Jull and Richardson (1994) contended that transversus abdominis and the oblique abdominals must be able to maintain their level of contraction tension to function optimally. This ability to maintain contraction would allow them to sustain their function of supporting the trunk. They described that the ability to sustain (a contraction) may need to be trained by progressing the time that a contraction could be held. They emphasized that retraining should involve low level maximal voluntary contractions. The authors suggested a goal of holding for ten seconds and repeating ten times. They hypothesized that motor control was the reason for the specific training needs of these muscles.

Sparto et al. (1997) examined endurance of trunk muscles to see what effect fatigue had on movement coordination. They hypothesized that postural stability would decrease with fatigue. In their subjects, the amount of greatest lumbar flexion increased with fatigue as a result of their lifting test. As well, there was increased anterior-posterior movement of the trunk center of mass. They hypothesized that this may have indicated decreased stability. Although this was a lifting task, it highlights the importance of endurance during a task involving trunk and leg function. The vertical jump also involves these muscle groups.

Several research groups have advocated for the importance of endurance for stabilizing musculature. In 2001, McGill highlighted the importance of endurance in stability, combined with the training of a neutral spine and co-contraction of abdominal muscles in a functional way. He reviewed the earlier work reported by Cholewicki and McGill (1996) in which moderate co-contraction of abdominals and paraspinals was enough to produce stability in the lumbar spine. He hypothesized that adequate stability during function was dependent on endurance, not strength, of the involved muscles. McGill defined endurance as the ability to maintain a force for a period of time (1998). His recommendation was that programs for stability should focus on endurance of the involved muscle groups with lower-effort exercises that were performed for longer times. He hypothesized that errors in motor control of stability would increase with fatigue. In his 1998 review, McGill highlighted 1995 Gardner-Morse findings that also suggested that stability may require endurance.

McGill et al. (1999) examined isometric trunk endurance. This was the only paper to examine different trunk endurance tests. They found reliability coefficients of > 0.97 for repeatability of the endurance tests. The researchers examined a normal population of men and women. They used timed holds of a right and left side bridge activity, an isometric flexion and an isometric extension position. They found that women had greater extensor endurance than men, while men had greater side bridge endurance. A general design weakness existed with the performance of all four positions on the same day. Although rest was allowed between different tests, it is possible that fatigue occurred (provided that the efforts were maximal). As well, the extension isometric test was ended when the body touched a platform 25 cm below the testing

surface. This implies that the subject may have slowly moved toward the floor until the floor was reached. If this entire time was counted, then the trunk is moving and this does not represent true isometric contraction. Rather, it would include eccentric trunk extensor work. There was also an inherent weakness in the side bridge position. This position would require considerable shoulder girdle stability and endurance on the weight-bearing side. Therefore, it would not be just an isometric trunk test. No other researchers have examined different types of trunk endurance tests.

Evans and Oldreive (2000) studied golfers with and without low back pain. Using a pressure bio-feedback unit, they found that the group with a history of lumbar pain demonstrated significantly less endurance in transversus abdominis than the other group. This study demonstrated that transversus abdominis, as a stabilizing muscle, required endurance for optimal function. This study assumed that transversus abdominis was responsible for the measured pressure.

Physiological evidence supports the argument for endurance as a factor in stability. Norris (1995 d) explained that transversus abdominis, internal oblique and external oblique are composed of mostly type I muscle fibers. He reported that these fibers are tonic contractors with low thresholds for recruitment. Their job is to stabilize, they are fatigue resistant, have high density of myoglobin, capillaries, and mitochondria, and they utilize oxidative metabolism. He explained that lack of use results in wasting of slow twitch fibers and a conversion of these fibers to fast twitch characteristics. This results in diminished capacity for endurance.

Contrary to the conclusions reached by the previous authors, Hodges and Richardson (1996) determined that transversus abdominis had a specialized role that

differed from the other abdominal muscles and from multifidus. When differing shoulder movements were performed, transversus abdominis activated before any of the other muscles activated. In fact, it activated before the shoulder actually moved. This activity was delayed in participants with lumbar pain. This delay was defined as a motor control problem. The authors reported that regardless of the strength or endurance capacity of the transversus abdominis, its contraction would not be effective in controlling the forces resulting from the arm movement (Richardson, 1996). Richardson et al. (1999) reinforced that lack of motor control, and not endurance or strength, seemed to be the difficulty with transversus abdominis in sufferers of lumbar pain.

In summary, there is some disagreement in the literature regarding the importance of endurance in the function of the trunk stabilizing musculature. Some researchers advocate that endurance plays an integral role, while others maintain that motor control is the primary factor determining stability. As well, the methods that have been used to test trunk stability endurance have had weaknesses. First, they have not represented functional positions. Second, in some methods there is the possibility of movement occurring, which means the test does not target true stability. Third, the methods previously used have in some cases relied a great deal on other muscle groups (e.g., the shoulders) in addition to the trunk stabilizers. In this case, it would be very difficult to control for all factors. It seems apparent from some of the literature that endurance may play a role in stability, but more evidence is needed to support these findings.

1.2.6 Muscle Strength and Hypertrophy

A well known effect of training for strength is hypertrophy of muscle. Hoeger and Hoeger (2002) highlighted some basic principles of strengthening:

1. Muscle should be loaded progressively and over time.
2. Training modes can be static (like stability exercises) or dynamic (movement exercises). In static exercises, the specific angles that the training occurs in are where the strength gains are made.

Sahrmann (2002) explained that loading muscle results in changes to protein in both muscle and connective tissue. Hypertrophy results in strengthening and stiffening of muscle and connective tissue. Stiffness enhances stability around joints.

Hakkinen (1989) reviewed his previous work in which he had determined that in untrained people, 10% strength gains can be seen in two weeks of heavy exercise. High performance athletes do not show gains as quickly. He described that in the untrained population, the early gains are attributed to neural changes that result from training.

Abe et al. (2000) studied the effects of resistance training on arms and legs in men and women. Training occurred 3 times per week for twelve weeks. Six exercises were completed for 8-12 repetitions to fatigue. For females, 1-repetition maximum chest press and knee extensor strength increased by the fourth week. Chest press strength increased by the sixth week in the men, and knee extensor strength increased by the second week. Both men and women experienced an increase in chest, tricep and 70% hamstrings (70% is a reference to the location of the measurement on the thigh) muscle thickness by the sixth week. Bicep thickness increased significantly by week 4 in men and week 8 in women. Thickness changes for quadriceps were not significant. They determined males

and females had similar percentages of strength and thickness increases. They identified previous research by Cureton et al. (1988) and Davies et al. (1988) who agreed that thickness changes in males and females were proportionate after resistance training. They also reviewed work by MacDougall et al. (1995) who determined that protein synthesis in muscle increased by over 100% one day after exercise. Abe et al. (2000) also concluded that their findings support that hypertrophy following high-intensity resistance training does not happen in less than 4 weeks.

To the author's knowledge, there has been no research on the course of hypertrophy in abdominals with any type of training. For this reason, abdominal muscle size will be examined in the present study in relation to two methods of training: trunk movement and trunk stability training.

1.2.7 Real-Time Ultrasound

Real-time ultrasound has been used as an objective measurement tool in clinical and research settings. Because the use of ultrasound is relatively recent in measuring muscle thickness gains, and due to the fact that it has never been used to measure the abdominals following exercise training, the literature will be reviewed here to assist in the understanding of this measurement tool. Hides et al. (1998) described how an image is created: pulses of ultrasound are sent into the body and reflections from tissues create pictures of internal structures.

Advantages of real-time ultrasound (Hides et al., 1995b) include accessibility, portability, cost-efficiency and lack of exposure to radiation. It also allows the ability to take precise measurements of individual muscles, which enables attention to detail not present in other methods of assessment (for example, tape measurements of muscle bulk

which do not distinguish between different muscles). Sipila and Suominen (1996) agreed that ultrasound allows precise muscle thickness and cross-sectional area measurements. Hides et al. (1998) reported that real-time ultrasound is safe in that there have been no situations of damage (to tissue) documented, and that no ill side effects are known.

Hides et al. (1995b) suggested that ultrasound would be useful in assessing how long a contraction can be held. They also suggested using ultrasound as a biofeedback mechanism during training of specific contractions. Sipila and Suominen (1996) reported that ultrasound has been used in populations of children with neuromuscular disorders, healthy children, elderly athletes, and men and women of different age groups. Several groups have studied trunk muscles. Misuri et al. (1997) used a B-mode ultrasound to measure changes in abdominal muscle thickness during breathing maneuvers. They noted that abdominal muscle activation was evidenced in changes of diameter (cross-sectional area). The study concluded that abdominal muscle thickness measures with ultrasound were repeatable. They reported that the abdominal muscles were identifiable because there are muscle sheaths between them. The authors took the mean thicknesses of the muscles over three to five repetitions of residual volumes and total lung capacities. They determined that in voluntary expiration, transversus abdominis was the primary generator of gastric pressure (Misuri et al, 1997). Two limitations of this study were the small sample size (six) and the entirely male sample. Hides et al. (1998) reported that real-time ultrasound is being used in the assessment and training of transversus abdominis and multifidus. They described specific uses for ultrasound with the abdominals. Superficial muscle (obliques and rectus) over-ride can be visualized. Right and left sides can be compared to ensure symmetry in transversus abdominis activation.

Co-activation of transversus abdominis during multifidus activation can be assessed. They also reported that both superficial and deep components of multifidus can be visualized segmentally, in a lying or standing position.

Elliot and Zylstra (2002) discussed the use of ultrasound imaging in the rehabilitation setting to test the function of deep abdominal muscles. Transversus abdominis and multifidus have been identified as segmental stabilizers and have been implicated as being dysfunctional in low back pain sufferers. They reviewed bio-feedback, stating that patients are allowed the opportunity to see effective contractions to optimize the use of exercise for pain control and functional gains.

Ultrasound has been used in other areas of the body in research. Upper and lower extremity musculatures have also been objectively measured using real-time ultrasound. Farthing and Chilibeck (2003) measured bicep brachii responses to concentric and eccentric loading.

In addition to its use in teaching contractions, real-time ultrasound can be used as an objective measure of treatment gains. Elliot and Zylstra (2002) reported that cross-sectional area was directly correlated to muscle hypertrophy. Hides et al. (1995b) identified that coefficients of variation for thickness measures in previous literature on quadriceps, tibialis anterior and multifidus were 2.5 to 7.6 %. Hides et. al (1996b) determined that in patients who received multifidus exercise training, recovery of size of multifidus was quicker than those that did not receive the exercise. Real-time ultrasound was used in these findings. No differences existed between the groups in terms of pain, disability, or range of motion. Hides et al. (1995a) identified ultrasound as a reliable tool for measuring multifidus size in young adults. Comparison

was made with MRI measures on multifidus bilaterally from L2-S1. Coefficients of variation in measuring multifidus thickness at L4 and L5 were 4 – 5.4%. They determined that adherence to protocol was imperative when using ultrasound as a measurement tool. Validity of measurement of quadriceps by ultrasound was obtained by Sipila and Suominen in 1993 using CT scan as a comparison. The correlation in calculated CSA's was 0.911 (Hides et al., 1995b).

Hides et al. (1995b) defined 4 limitations of real-time ultrasound:

1. Reliability depends on the experience of the person operating the ultrasound unit.
2. Fat deposits in muscle can affect thickness measures (in the elderly or in muscular dystrophy).
3. For use as an objective measure, pilot studies must be completed.
4. Cross-sectional measurements of big muscles are difficult.
5. In 1998, Hides et al. added that ultrasound images will not display the entire length of a large muscle. This would be more of a problem when ultrasound is used in bio-feedback. In thickness measures, this challenge should be accounted for in the pilot studies where the researchers demonstrate they can reliably localize the same position in the muscle for measurement on successive occasions.

Hashimoto et al. (1999) determined that the linear ultrasound transducers (probes) define a wide field of view so the structure and other surrounding structures can be seen. As well, linear transducers can clearly image superficial or close structures. A linear probe was used in the present research study. Hashimoto et al. (1999) also described what is seen in normal anatomy. They specified that muscles are dark, and fibroadipose septa, epimysium and fascia are light.

Hides et al. (1995b) reviewed that for multifidus, repeated measurements could be used to evaluate hypertrophy as a result of rehabilitation. It stands to reason, therefore, that serial measurements could also become useful in evaluating the training of normal muscle.

To summarize, no studies have measured repeated abdominal muscle thicknesses in normal participants as a result of performing movement and stability training programs. We have seen that the ultrasound technique allows specific, safe muscle thickness measurements. Its use has not been fully explored for the abdominals. To understand if and how abdominal muscles hypertrophy as a result of training would further the current knowledge of abdominal muscles and abdominal exercise prescription.

1.2.8 What is Missing in the Literature?

There is a lack of research that examines trunk stability in relation to functional, or sport, measures. Norris (1995b) described the areas in the lumbar spine that are susceptible to movement. The intervertebral discs, the zygoapophyseal or facet joints and their capsules, the ligaments, vertebral end-plates, and the junction between the lumbar spine and pelvis are all areas where movement can occur. Many different directions of movement are possible. So during function, this also means that movement can occur in a variety of unwanted directions. Richardson et al. (1990) reported that impaired stability would be a problem for difficult sports and exercise training. Despite this, the influence of trunk musculature on sport measures has not been rigorously examined. In theory, trunk stability should be influential on sporting skills (e.g., the vertical jump). According to Norris (1995d), the role of the stability muscles is to oppose gravity. They control small forces for prolonged times. When they are not used, or trained, their ability to

sustain or endure loading is decreased. As Norris (1995e) suggested, specific stimulation (recruitment/training) of the stability muscles will result in faster muscle reaction times. He also reported that this recruitment of stability muscles has demonstrated improved stability of peripheral joints, the pelvis, and the lumbar spine. He reasoned that if the (stability) muscles can respond quickly to the application of outside forces on the body, there should be an improvement in function. Jull and Richardson (1994) have concluded that stability involves automatic muscle synchronization to control postures and functions. As previously noted, trunk stability can influence dynamic movements. Enoka (1994) explained the organization of muscle and neural control in the body. He said that the neural control of one muscle has an effect on the entire body's movements. It stands to reason, then, that a stable trunk should be critical for maximal efficiency of movement, regardless of the skill being performed.

An effective method for improving vertical jump by training trunk stability will be examined in this study. There is no published research on this topic. Many authors have indicated coordination, control, and balance as paramount in optimizing jump. However, no published work has considered the role the trunk might play in such functions. Exercise specificity will be explored by comparing stability exercises for the trunk versus movement exercises for the trunk. The result of the training on vertical take-off velocity will be measured. The influence of these training regimes on abdominal muscle hypertrophy and trunk stability endurance will also be examined. No previous work has examined how strengthening or increasing endurance of the trunk muscles could affect a functional performance like the vertical jump. We know that hypertrophy can influence power, but we don't know if hypertrophy of abdominals will influence

power, and therefore, vertical jump performance. Also, stability research indicates control as an important result of stability, but we do not know if improving endurance of stabilizers will improve the vertical jump through increased trunk control. If control is an important part of stability as the literature suggests, and control/coordination has been said to be effective in vertical jump, then stability training should increase the performance of vertical jump. Likewise, if endurance is an important condition of stability, increasing endurance should improve postural stability as termed by Sparto (1997). Therefore, this should improve control for jumping. Thus, increasing control should allow for more effective work output during push-off in the countermovement jump.

1.3 Statement of the Problem and Hypotheses

1.3.1 The Problem

Does the type of training (trunk stability exercise vs. trunk movement exercise) influence vertical jump performance differently?

1.3.2 Research Hypotheses

1. Trunk stability training will result in greater vertical take-off velocity than trunk movement strengthening or a control group (refer to page 23, section 1.2.4 for background).
2. Trunk stability training will result in greater hypertrophy of transversus abdominis than trunk movement strengthening or a control group (based on the definition of transversus abdominis as a trunk stabilizer (Norris, 1995c & d)).

3. Trunk movement strengthening will result in greater hypertrophy of rectus abdominis than trunk stability training or a control group (based on the definition of rectus abdominis as a trunk mover (Norris, 1995d & e)).

4. Trunk stability training will result in a greater increase in stabilizing endurance of abdominal muscles than trunk movement strengthening or a control group (refer to page 27, section 1.2.5 for background).

1.3.3 Assumptions

It was assumed that:

1. All subjects answered pre-testing questionnaires honestly, including their previous training history, as well as their previous history of lumbar, neck or leg pain.
2. All subjects documented their activity on their diaries accurately, and did not begin any other new training regimes for their abdominals over the course of the study period. Subjects also did not stop any regular exercise routine during the course of the study period.
3. All subjects completed the number of exercise sessions that they said they had completed on their activity diaries.
4. All subjects complied fully with the pre-testing restrictions.
5. Vertical jump outputs were maximal.
6. Modified double leg lowering outputs were maximal.
7. Learning in vertical jump and leg lowering tests was controlled for by education and practice.
8. Males and females performed the same.

1.3.4 Limitations

There was a large variance in age, abilities and activities of daily living of this normal population. Also, because of the large number of subjects, it was not possible to test people during the exact time of day or environmental situations (i.e. temperature, quietness of testing area). Any equipment error outside of calibration would pose problems.

1.3.5 Delimitations

The study results are applicable in the normal population with an age of 28.9 ± 9.6 years (mean \pm standard deviation) with no neck, back or leg pain, no heart disease, and a history of training abdominals no more than 3 times per week. The results of this study may not be applicable to children, elderly, injured, ill or athletic populations. There was a large range of age and skill sets in this sample, which would affect the generalizability to the normal population.

Chapter 2 – Methodology

2.1 Research Design

The design chosen for the research study was a randomized groups, controlled true experimental (Thomas and Nelson, 2001), repeated measures design. Sample selection was purposeful to ensure the number of subjects required for adequate power. It was determined that if the sample size in each of the 3 groups was 21, a one-way analysis of variance would have 80% power to detect at the 0.050 level a difference in variance of the means of 0.020 m/sec, representing a mean difference between means of 0.3m/sec, assuming that the common standard deviation is 0.351.

Random assignment of 59 subjects into three groups (trunk movement, trunk stability, and control) occurred. Each subject had an equal opportunity to be randomized into each of the three groups, to ensure true random assignment. Subjects performed their exercises (or stretches for controls), 3 times per week for 12 weeks. With movement and stability groups, a weekly check-in session was scheduled with the researcher to evaluate the exercise technique and advance the training programs. The control group participants were contacted at home by the researcher once every two weeks to ensure compliance to the stretching program. The control group was a weightless control, which means the control participants were offered the ability to receive the movement and stability programs and to be educated in those exercises following the study. Actual meetings or contacts completed compared to those scheduled were 77.5% for controls, 51.1% for the movement group and 57.4% for the stability group. Summer holidays, work schedule conflict, and missed appointments were the major reasons for unsuccessful contacts.

Prior to initiation of the program, participants were provided with a letter of information (Appendix A) explaining the purpose of the study, procedures, possible benefits and risks, and voluntary nature of participation. Contact numbers for researchers and rights of participants, including the right to withdraw from training were explained therein. A consent form was completed by the participants (Appendix A). A list of pre-test restrictions was provided for the participants to read and sign (Appendix B).

Participants also completed a pre-test restriction list and questionnaire as well as a check for exclusion criteria (Appendix B) to ensure suitability for participation. Reminders of the restrictions were given prior to the second and third sessions of testing. The pre-testing questionnaire included data on age, weight, height, gender, contact information, and a historical check of history of back, neck or leg pain, heart disease, and presence of current abdominal training greater than three times per week. All participants were provided with an activity diary (Appendix C) to document times that they performed their specific exercises as well as any other common or different exercises they undertook within the twelve week period of the training. Finally, participants were provided with pictures and descriptions of their respective exercise programs (Appendix D). Movement and stability groups were also mandated to perform the control group stretching before and after exercise to minimize the risk of injury.

Prior to initiation of the twelve week program, reliability pilot studies were used to examine repeatability for abdominal thickness and trunk stability endurance measures (see Appendix E for data collection sheets). Twelve subjects were tested for abdominal thickness and 10 for endurance. This was a purposeful sample of volunteers, some of which may have participated in the 12 week study. At least two days occurred between

the test and retest sessions. The same researcher did all measurements on both days (as well as on all testing occasions throughout the twelve week program).

A familiarization session was provided to each subject prior to the first testing session at week zero. Training began at week one. The second testing session occurred at week three, and the final testing session at week twelve. The familiarization and testing procedures will be reviewed in detail in later sections. This research was approved by The University of Saskatchewan Advisory Committee on Ethics in Human Experimentation (Biomedical Sciences) (Appendix F).

2.2 Participants

Fifty-nine volunteers were recruited from the University of Saskatchewan and city of Saskatoon via posters in University of Saskatchewan buildings as well as fitness clubs across the city (Appendix G). Forty females and 19 males began the study. Twenty subjects started in the stability training group. Twenty-one subjects began in the movement training group. Eighteen subjects began in the control group. Nine subjects were lost during the study due to noncompliance. Some of these nine subjects dropped out of the study, and others were excluded for reasons of noncompliance. The stability group finished with 18 participants. Sixteen participants finished in the movement group. Sixteen also finished in the control group. Descriptive data for participants completing the study are included in Tables 2.1 and 2.2.

The expectation for training frequency was 3 times a week for 12 weeks (36 sessions). A minimum of 24 sessions (67%) completed was required for training compliance. This value was based on a minimum of 2 sessions per week for 12 weeks.

This minimum value was selected by the researcher. Participant data not meeting this minimum requirement were not used in the results.

Table 2.1 Descriptive Data For Total Group

	Mean Statistic	Std. Deviation Statistic	Skewness Statistic	Std. Error	Kurtosis Statistic	Std. Error
age	28.92	9.60	1.16	.34	.40	.66
kg	71.04	12.78	.63	.34	-.86	.66
cm	170.26	9.87	.46	.34	-.76	.66

Table 2.2 Descriptive Data By Training Group

training group = stability

	Mean Statistic	Std. Deviation Statistic	Skewness Statistic	Std. Error	Kurtosis Statistic	Std. Error
age	28.89	10.39	1.70	.54	2.33	1.04
kg	72.58	13.78	.72	.54	-1.09	1.04
cm	170.16	10.85	.34	.54	-.71	1.04

training group = movement

	Mean Statistic	Std. Deviation Statistic	Skewness Statistic	Std. Error	Kurtosis Statistic	Std. Error
age	32.56	9.78	.27	.56	-1.37	1.09
kg	71.39	12.80	.62	.56	-.58	1.09
cm	168.89	10.02	1.02	.56	.31	1.09

training group = control

	Mean Statistic	Std. Deviation Statistic	Skewness Statistic	Std. Error	Kurtosis Statistic	Std. Error
age	25.31	7.42	1.76	.56	2.50	1.09
kg	68.97	12.13	.53	.56	-1.06	1.09
cm	171.76	8.95	.24	.56	-1.46	1.09

2.2.1 Inclusion Criteria

1. males or females over 18 years of age.

2.2.2 Exclusion Criteria

1. presence of back, neck or leg injury or pain.
2. presence of ischemic heart disease.
3. current abdominal training more than three times per week.
4. less than 67% compliance with training program.
5. inability to complete a testing protocol correctly
 - inability to perform the requested style of vertical jump
 - inability to abstain from activities that would activate abdominals 24 hours prior to testing (activation of abdominals would encourage blood flow to the site and abdominals would appear larger than normal on ultrasound measurements)
6. initiation of a new exercise training program during the course of the study.

2.3 Procedures

2.3.1 Familiarization

All participants received the same standardized education before testing. The familiarization procedure used was from the protocol of Butcher (2001). Participants watched a video of correct abdominal co-contraction and double straight leg lowering procedure. The investigator inquired as to whether the participants had any questions about the video.

Hagins et al. (1999) devised a trunk stability education method from the principles developed by Richardson and Jull (1995) which involves co-contraction of

transversus abdominis and multifidus being used to achieve a stable neutral spine.

Butcher (2001) modified Hagins' protocol to incorporate the double straight leg lowering test.

The video began with participants practicing maximal posterior and anterior pelvic tilts in four point kneeling (these positions correspond to lumbar flexion and extension respectively). The subjects then found a mid-range position of lumbar lordosis. This was accepted as the probable neutral position (Butcher, 2001). Participants were then educated in and practiced Richardson and Jull's (1995) abdominal hollowing-in maneuver. Participants repeated the above tasks in supine.

Participants were then shown the double straight leg lowering technique, were educated on the testing of the double straight leg lowering and were allowed to practice. The participants' performance of the co-contraction was examined. Butcher (2001) utilized the definition of a successful performance from that of Hagins et al. (1999). The technique had to occur without shoulder elevation, without neck flexion or extension, and without pelvic anterior or posterior tilt (Butcher, 2001). The assumption following familiarization of the double straight leg lowering technique was that learning would not occur during the successive testing sessions, as all participants had been equally educated and allowed to practice before the study began.

2.3.2 Testing Procedures

Testing procedures were performed in the same order for all participants due to the necessity of measuring abdominal thickness in a relaxed state of the abdominals. Ultrasound measures for abdominal thickness were performed first, followed by a double straight leg lowering trunk stability measure, vertical jump, leg strength testing and

finally a double straight leg lowering trunk endurance measure. This order was selected due to the fact that the researcher desired as long a time span as possible between the double straight leg lowering trunk stability measure and the double straight leg lowering trunk endurance measure, to allow rest following the first measure. Appendix H details pictures of testing equipment and procedures.

2.3.2.1 Abdominal Thickness Measures

A reliability pilot study was conducted on the B-mode ultrasound (Aloka SSD-500, Tokyo, Japan) to ensure repeatability for abdominal muscle thickness measures. Results are listed in section 3.1.1 Pre-Testing Data.

Abdominal thickness measures were done before all other tests on each participant, to ensure the abdominals were at rest when the measures were taken. Instructions to participants were standardized. The researcher performed all measures during all testing weeks. The researcher was not blinded, however, to training group. B-mode muscle ultrasound was used to measure thickness of rectus abdominis (selected as a trunk mover as defined by Norris, 1995d & e) and transversus abdominis (selected as a trunk stabilizer as defined by Norris, 1995c & d). The muscle location protocol of Misuri et al. (1997) was repeated for this study. Misuri et al. (1997) used a B-mode ultrasound with the probe positioned on “the lateral wall of the abdomen midway between the costal margin and the iliac crest, along the right anterior axillary line. For rectus abdominis, the probe was placed 2-3 centimeters above the umbilicus, 2-3 centimeters from the midline” (Misuri et al., 1997, p.2863) to measure abdominal thickness. A procedure adapted from Farthing and Chilibeck (2003) for bicep measures and also used by Stokes and Young (1986) was followed to ensure exact positioning of the ultrasound probe on each

measurement occasion. For this study, participants laid supine with hips and knees flexed up to encourage a neutral lumbar position, relaxed abdominals and maximal comfort. The anterior abdominal wall was exposed. An optimal ultrasound view was obtained. This probe location was then marked on the participant's skin with marking pen. An overhead transparency with a hole the exact size of the ultrasound probe was then placed on the abdomen. The navel, any hairs on the abdomen, the linea alba, and any moles or scars were traced onto the transparency. On the repeat measurement, the transparency was used again, positioned according to the tracings and navel position, and the exact probe location was used as for the first measurement.

Water-soluble transmission gel was applied to the skin and the probe was gently placed on the abdominal skin, perpendicular to the skin's surface, with the locator arrow on the probe positioned pointing in a cephalad direction. When a clear view of the abdominals was obtained, the screen was frozen and thickness measures were taken separately of rectus abdominis and transversus abdominis via a moving cursor. Measurements were always taken 2 cm from the proximal end of the probe (this marking appeared on every screen). The method by Farthing and Chilibeck (2003) was again used. Three separate screens, and therefore separate measures, were taken for each muscle. The mean of the two closest values was the final score for each individual muscle. If a median value was present, a fourth screen and measurement were taken. For the ultrasound, the chance for error was in the measurement technique, so using mean values allowed for regression to the mean and by using the two closest, we eliminated any outliers.

2.3.2.2 Trunk Stability Testing

A modified double straight leg lowering test developed by Butcher (2001) was used for this study. The researcher performed all testing for this trunk stability measure. A plexiglass support (Appendix H) in the shape of a neutral lumbar lordosis was used to hold the sphygmomanometer tightly while it was inflated prior to each use to ensure no deflation and inaccuracy of results. The pressure chosen was 40 mm Hg (Wohlfahrt et al., 1993). 40 mmHg was utilized to standardize the protocol, however the researcher acknowledges that there will be limitations with a standardized pressure due to the fact that individuals have differing body types. The participant lay supine with his buttocks near the end of a table and his hands crossed over his chest (Appendix H). The sphygmomanometer was placed, inflated, under the lumbar spine just proximal to the sacrum. The participants' legs were held at 70°. In the instance of tight hamstrings, very slight flexion of the knees was utilized to prevent lumbar flexion and thereby increasing the pressure on the sphygmomanometer cuff drastically.

The modification by Butcher (2001) was in the locating of neutral spine by the participant. The participant was required to adjust the spine and pelvis until the cuff gauge read 40 mm Hg. A goniometer (Appendix H) was utilized to measure leg angle. The axis was set at the right greater trochanter. The measuring arm lined up with the center of the femur. Seventy degrees was the starting angle. The participants performed the abdominal hollowing-in maneuver to keep 40 mm Hg on the gauge, then lowered their legs as much as possible until the pressure fell below 30 or crept above 50 mm Hg. At this point, the test was terminated and the angle was read on the goniometer. The angle achieved was converted to a value representing the relative leg gravitational torque

at the hip joint resulting from the leg weight. This value is written as a percentage of total potential torque created if the legs were horizontal (a perfect score). The relative leg gravitational torque value is the cosine of the test angle achieved multiplied by 100% (Butcher, 2001). The participant performed the modified double straight leg lowering maneuver three times, resting one minute between each time. The lowest angle or best score (closest to horizontal) was used as the test score. The relative leg gravitational torque calculation used by Butcher (2001) was as follows:

$$\text{relative leg gravitational torque} = \frac{\cos(\theta) \text{ recorded}}{\cos(\theta) \text{ perfect score}} * 100\%$$

Butcher determined the reliability of this method to be 0.98 using an Intraclass Correlation Coefficient calculation.

Criticism of the double-leg-lowering maneuver has been noted. Zannotti et al. (2002) reported that double-leg-lowering scores should be questioned because there seems to be an uncontrollable anterior pelvic tilt that occurs during the maneuver. The scores they referred to are muscle grades from 2 through 5 (Zannotti et al., 2002) that depend on how low the participants lower their legs without anterior pelvic tilt. It is important to clarify, however, that the authors described the objectivity of the test as a mere palpation of the initiation of anterior pelvic tilt. In the present research study, we objectively measured the change in pressure with a sphygmomanometer under the lumbar spine. The test was terminated if the pressure rose over 50 mm Hg or fell under 30 mm Hg as noted. This allowed for mild variations in pressure which should take into account lumbopelvic rhythm which is natural and must occur (in function as well as in testing procedures). Reliability has been demonstrated in this modification of the test (Butcher, 2001). Zannotti et al. (2002) described that the aim was to hold the lumbar spine flattened

against the table during the test. In the present study, the aim was to maintain 40 mm Hg pressure on the sphygmomanometer, which was accepted as a standardized neutral lumbar lordosis. Another major difference between the protocol utilized by Zanotti et al. (2002) and the present study protocol was that in their study, the participants held onto the table above their heads while performing the leg lowering. The present study standardized hand position by placing the arms crossed over the chest. If hands were placed overhead, there is a possibility that tight latissimus dorsi musculature could cause hyperextension of the lumbar spine, and a resultant exaggerated anterior pelvic tilt. In summary, because the grading scheme was not utilized in the present study and because of the key differences in protocol between the Zanotti et al. (2002) study and the present study, it is felt by the present author that the skepticism of Zanotti et al. (2002) regarding the double-leg-lowering maneuver is not applicable to the present study protocol.

2.3.2.3 Trunk Stability Endurance Testing

Trunk stability endurance was measured by a test developed for the purpose of this research study. The researcher performed all testing for trunk stability endurance. A modification was made to the double straight leg lowering stability test used by Butcher (2001). The plexiglass support, sphygmomanometer, goniometer and an assistant were used as for the stability double straight leg lowering test. In this case however, the starting angle was the critical component of the test. As endurance implies a prolonged effort of trunk control at a sub maximal load, the maximal leg lowering score for each participant could not be used. Also, the same angle could not be used for every participant as their abilities were so variable that this would have put some of the participants at a distinct disadvantage. Instead, each participant's best score from the

double straight leg lowering test was taken and converted into an endurance calculation. This way, the test was standardized to the individual. The relative leg gravitational torque calculation (before conversion to a percentage) was multiplied by 60 % (60% was chosen as a sub maximal value for the present study). This gave us an angle that was 60% of the torque of the best leg lowering score. A sample calculation is given below:

a.
$$\text{relative leg gravitational torque} = \frac{\cos(\theta) \text{ recorded}}{\cos(\theta) \text{ perfect score}} = n$$

b.
$$\text{endurance angle} = \cos^{-1}(n * 0.6)$$

This became the start point for the endurance test. The assistant held the participant's legs (angle ensured by goniometer measurement) at this angle. Instructions were standardized to participants. They performed their abdominal hollowing-in technique to maintain 40 mm Hg pressure on the sphygmomanometer. Once their legs were released, the participant held their legs in this position as long as possible. The researcher timed their trial with a stop watch. Because of the fatigue that would result from this event, only one trial was performed. Success was determined as per the criteria for the double straight leg lowering stability test. The participant had to maintain pressure between 30 and 50 mm Hg, they could not use compensatory techniques, and they could not lift their legs above the level of the angle (which would have made it easier due to less torque). If their legs dropped below, they were allowed to vary by 1-2° as determined by the researcher. After this limit, the test was stopped and it was determined that they were unable to maintain their leg position. On the third and twelfth week of testing, the individual's same starting angle was used so a comparison could be made between weeks.

2.3.2.4 Vertical Jump

The protocol used by Butcher (2001) was repeated for this study. All instructions to participants were standardized. Participants were allowed to practice one jump. They were required to hold a wooden dowel across the top of their shoulders and upper thoracic spine to take the upper extremities out of the jump. This position eliminated the possibility of arm strength contributing to the vertical jump performance. The participant was required to stand perfectly still on the vertical jump platform until cued to jump. At this point, they performed a maximal countermovement jump (Butcher, 2001). After a brief rest, this procedure was repeated until three successful trials were achieved. Success was determined by the ability to hold perfectly still (so the mass of the participant could register on the force plate) and to generate sufficient force during take-off to exceed a pre-set threshold on the computerized force platform. If this was not met, the jump had to be repeated. The force platform could be set for different masses to ensure sensitivity regardless of participant mass. Customized software developed by Sprigings, University of Saskatchewan, was used to convert vertical impulse (force x time) values to take-off velocities. The best take-off velocity was used as the jump score.

2.3.2.5 Leg Strength Testing

The researcher and volunteers collected data for leg strength testing, following a standardized protocol. Participants performed two minutes of stationary cycling to warm up prior to the leg strength test. The purpose of the test was to achieve a calculated one repetition maximum. As per the procedure used by Butcher (2001), participants sat on the leg press machine, placed their feet in a standardized spot, gripped the specified handles, and were strapped in to prevent rising off the seat and using trunk extensors

during the test (see Appendix H photo). The seat was positioned at the same distance for each testing session for a participant. This distance was determined by a 70° angle measured at the knee joint (with the feet comfortably in place) on the first testing occasion.

The test began with a warm up of 10 repetitions at a low load, followed by a one minute rest, and then by another warm up set at the same load. Two minutes rest occurred prior to the maximization trials. The goal was to determine a weight (in less than four trials) that the participant could not push more than 10 times. If a participant pushed more than 10 times, they rested for two minutes and the weight was increased. The formula used by Ware, Clemens, Mayhew and Johnston (1995) was utilized to determine the 1 repetition maximum:

$$1 \text{ repetition maximum} = (\text{weight lifted on final trial}) (0.033) (\text{repetitions performed}) + (\text{weight lifted on final trial})$$

2.3.3 Exercise Programs

2.3.3.1 Control Group

The control group performed a series of stretching exercises twice per day, three times per week (Appendix D). They were also provided with a list of safety instructions related to stretching (Appendix D). They were contacted by telephone or email every second week by the researcher to ensure they had not initiated any new workout programs over the course of the 12 week study period, and to ensure they were doing the stretches as requested as well as documenting their stretches and normal activities on their activity diaries.

2.3.3.2 Stability and Movement Groups

The stability and movement groups performed their respective exercises three times per week. An attempt was made to hold weekly individual meetings to review exercise technique, progress exercises, and ensure participants had not started any other new workout programs over the course of the study period.

The progression of stability and movement exercises was designed according to anatomical definitions of movement planes. The researcher felt that by designing the programs by defined planes of movement, the groups would be very comparable as they were experiencing the same moments during exercise, but with different principles of exercise. The planes define the motion at a joint that occurs during the exercises (Levangie and Norkin, 2001). The planes are designed with the anatomic position in mind (a body is standing face forward with palms forward). The first plane is the sagittal plane. Both flexion and extension occur in this plane, so the body is separated into right and left (Figure 2.1).

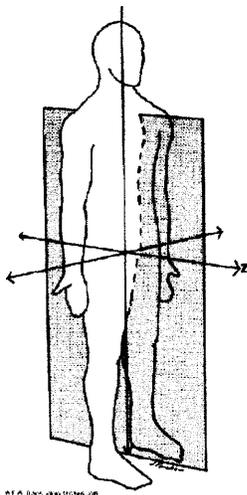


Figure 2.1 Sagittal plane (Levangie and Norkin, 2001)

The frontal plane is the sidebending plane that separates the body into front and back (Figure 2.2).

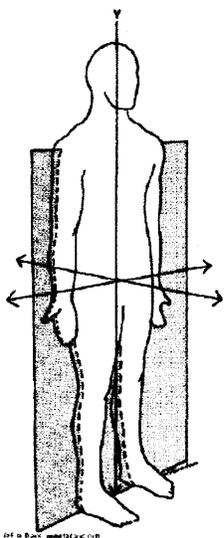


Figure 2.2 Frontal plane (Levangie and Norkin, 2001)

The transverse plane is the rotary plane which separates the body into top and bottom halves (Figure 2.3).

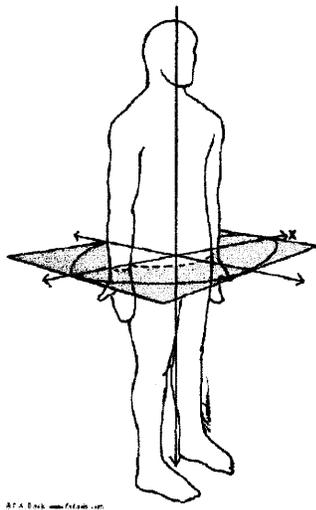


Figure 2.3 (Levangie and Norkin, 2001)

Finally, a group of exercises was also selected out of a combination of the mentioned planes (sagittal, frontal and transverse). In all, there were five sub-sections of exercises for the stability group and five for the movement group (Appendix D). They were:

- 1) sagittal plane flexion exercises
- 2) sagittal plane extension exercises
- 3) frontal plane exercises
- 4) transverse plane exercises
- 5) combined plane exercises

Each sub-section consisted of five to six progressions of exercises, beginning with the easiest and progressing to the most difficult exercise in the set. Participants were responsible for performing one exercise at a time out of each sub-section. Each participant was started at the most difficult exercise they could perform (in each sub-section) with the proper technique. They were progressed within a sub-section according to their success with each exercise. This allowed each participant's program to be very individualized. Participants performed five exercises total and were progressed by the researcher at an individualized pace in each of the sub-sections. If a participant missed a meeting, he or she was contacted by the researcher to rebook the meeting.

2.3.3.2.1 Stability Group

Richardson and Jull (1995) reported that isometric exercise is most beneficial for re-educating the stabilizing role of deep local muscles of the lumbar spine. They also indicated that following re-education, isometric exercises for the deep lumbar muscles can be combined with dynamic functional exercise for other parts of the body

(Richardson and Jull, 1995). They also argued that stability muscles should be trained by holding low level, tonic maximal voluntary contractions. Other principles they utilized included beginning training in anti-gravity positions with no resistance, keeping loads at a low level, and advancing to functional positions and dynamic movement when appropriate. These principles were followed by the present researcher for the development of progressions within the stability group exercises.

Once the appropriate exercise in each sub-section was chosen for a participant, he or she progressed along increments of seconds of holding the contraction and repetitions of the exercise. The exercise was initially held for five seconds and done for five repetitions, then progressed to eight then ten seconds. Once the participant was successful at ten seconds, they maintained the ten second hold but performed eight and then ten repetitions. A rest equal to the amount of time a contraction was just held, was taken between repetitions. So the goal to achieve for each exercise, before progression to the next more difficult exercise in the sub-section, was a ten second hold and ten repetitions, as described by Richardson and Jull (1995). At this point they determined that load and functional demand (functionally specific positions) could then be added. Each exercise in the individual sub-sections then, gets progressively more difficult.

The sagittal flexion sub-section of exercises began in supine, progressed to increasing difficulty of load with leg length increasing the torque away from the trunk, and to the final position which was a more functional, upright or anti-gravity position. Transverse plane exercises began again in supine, progressed with first arms and then legs being utilized to increase the torque away from the trunk (at angles to the body as per the definition of transverse plane discussed earlier) and finally ending in an

antigravity position. Frontal plane exercises began with symmetrical arm lifting in standing, and progressed to exercises where the entire trunk weight is supported side lying on an elbow and knee, then an elbow and foot, and finally to a dynamic movement where the participant maintained the body weight on elbow(s) and foot (feet) while rolling from right to left. Combined planar exercises utilized both arms and legs at oblique angles to the body to gradually increase the torque or load. Finally, the sagittal extension exercise began with a supine bridge, decreased the base of support by using a one-leg bridge, switched to a prone elbow supported leg raise, arm and leg raise, and finally, the most difficult exercise was a half-sit where the person stood, performed their hollowing-in maneuver, and sat back slightly (unsupported) while not losing their neutral lordosis.

2.3.3.2.2 Movement Group

The movement group performed dynamic exercises. Exercises were again progressed by increasing lever arms (and therefore torque) as well as progressing to more functional, upright, and less supported positions. As Cissik (2002) suggested, abdominal exercises should be progressively more difficult as fitness and skill improve.

The progressions chosen for movement exercises were two sets of 12 repetitions, followed by 2 sets of 15 repetitions, 3 sets of 12 repetitions, and finally 3 sets of 15 repetitions. One minute rest was taken between sets of exercise. Three minutes rest was taken between different exercises. The alactic acid system (CP-ATP) is used for exercise that lasts less than ten seconds. After one minute of rest, this has been restored by 75%. After three minutes, it has been totally restored (Craven, 2001).

The sagittal flexion sub-section began with curl-ups whose difficulty progressed by differing arm placement (from beside the body in the first exercise to the most difficult exercise where the arms were outstretched overhead). The transverse plane began with supine work and progressed to functional seated and standing positions. Resistance was increased by the participant holding a dowel over their shoulders and then attaching resistive tubing to the dowel and turning against the tubing. The frontal plane exercises began with supine side crunches (anti-gravity), progressed to a functional standing exercise, and then to a side lying position for side crunches, where the participant was required to lift his or her body weight against gravity. The combined plane exercises consisted of oblique crunches with progressively more difficult hand positions as per the sagittal flexion group. It ended in the final exercise which required the participant to maintain arms outstretched overhead (to one side) while lifting the opposite leg to meet the arms in the center. Finally, the sagittal extension exercises began prone, progressed again with increasingly more difficult hand positions and added leg lifts, and ended in a functional upright modified dead lift exercise. In this final exercise, tubing again provided resistance for the participant to work against.

2.3.4 Statistical Analysis

SPSS 11.01 for Windows 2000 was utilized for all statistical analyses. An ANCOVA with repeated measures was used to assess first, the effect of movement training, stability training and no specific training (control) on vertical jump. Body mass, week zero jump, and leg strength were covariates for the analysis. This was a 3 x 2 (group x time) ANCOVA. Two secondary analyses were performed. These assessed the effect of movement training, stability training and no specific training on trunk stability

endurance and abdominal muscles thicknesses. For trunk stability endurance, week zero scores were used as covariates. For abdominal muscles thickness measures, body mass and leg press scores were used as covariates. Week zero scores were not used in this case because the error lies in the ultrasound measurement, not in the possibility of the participant learning a particular skill.

Statistical significance testing in this study was determined using $\alpha < 0.05$. The SPSS syntax was modified to include post-hoc analyses that would compare individual differences following a significant group x time interaction (Appendix I).

Chapter 3 Results and Discussion

3.1 Results

3.1.1 Pre-Testing Data

Prior to initiation of the 12 week program, reliability pilot studies were conducted to examine repeatability for abdominal thickness and trunk stability endurance measures (see Appendix E for data collection sheets). The intraclass correlation coefficient calculated for trunk stability endurance for the pilot study was 0.95. For abdominal thickness measures, intraclass correlation coefficients were calculated separately for rectus abdominis (0.95) and transversus abdominis (0.82). Vincent (1999) reported that intraclass reliability is useful on two or more measures, and its sensitivity includes changes in order and mean differences of the values. Values greater than 0.90 are highly reliable and .80 to .89 are moderately reliable.

3.1.2 Background Data

For the 12 week study, the stability group started with 20 participants. After 12 weeks, 17 stability participants' data were eligible for abdominal thickness analysis, 18 were eligible for jump analysis and 16 were eligible for analysis of endurance scores. The movement group began with 21 participants. After 12 weeks, 16 movement group participants' data were eligible for analysis of abdominal thickness and endurance scores, and 14 were eligible for analysis of jump scores. The control group started with 18 participants. After 12 weeks, 14 control group participants' data were eligible for analysis of jump scores and abdominal thickness scores, and 16 were eligible for analysis of endurance scores. The participant data that was included met overall minimal inclusion criteria (67% of training completed), although the researcher cannot report compliance between the two periods of the study (week 0-3 versus week 3-12),

The participants' data that were ineligible for analysis were lost due to noncompliance with training or testing protocol, or the inability to complete training or testing protocol. No obvious differences were identified for vertical jump, abdominal thickness measures, or the trunk stability endurance measure for the week 0 or 3 (where available) scores of the participants who did not complete the 12 week program versus the scores of those who finished the 12 week period.

A one-way ANOVA was calculated to ensure that there were no significant differences between the randomized groups for the variables of age, body mass and height ($\alpha = 0.05$, Table 3.1). There were no significant differences noted. The Levene's statistics were also not significant, meaning there were no significant differences between the variances of each group. This relates to a basic assumption of ANOVA called homogeneity of variance: variability of the samples is equal or nearly equal (Vincent, 1999). Mean values for the stability group were 28.9 years, 72.6 kg body mass and 170.2 cm height. Mean values for the movement group were 32.6 years, 71.4 kg body mass and 168.9 cm height. Mean values for the control group were 25.3 years, 69.0 kg body mass and 171.8 cm height.

Table 3.1 Oneway ANOVA - Comparing Age, Height, Body Mass Between Groups

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
age	1.46	2	47	.24
kg	.24	2	47	.79
cm	.15	2	47	.86

ANOVA

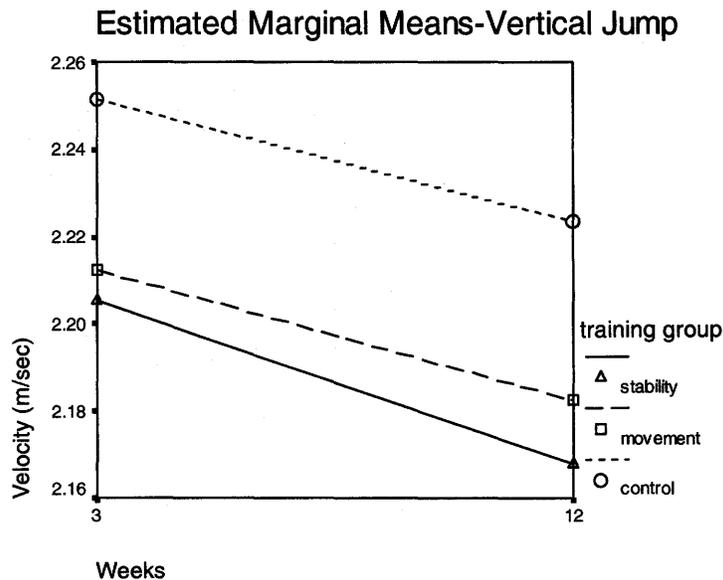
		Sum of Squares	df	Mean Square	F	Sig.
Age (years)	Between Groups	420.53	2	210.26	2.41	.10
	Within Groups	4097.15	47	87.17		
	Total	4517.68	49			
Body Mass (kg)	Between Groups	112.85	2	56.42	.34	.72
	Within Groups	7889.77	47	167.87		
	Total	8002.62	49			
Height (cm)	Between Groups	65.88	2	32.94	.33	.72
	Within Groups	4707.27	47	100.16		
	Total	4773.16	49			

A repeated measures analysis (general linear model) for body mass identified no effect for group [$F(2, 46) = 0.132, p = 0.877$]. This analysis ensured that there were no differences in body mass between groups. Mean values for week 0 body mass were 71.6 kg for the stability group, 71.4 kg for the movement group and 69.0 kg for the control. For week 3 body mass, mean values were 68.3 kg for the stability group, 71.2 kg for the movement group and 68.5 kg for the control. For week 12 body mass, mean values were 71.1 kg for the stability group, 71.2 kg for the movement group and 69.0 kg for the control. The general linear model also indicated no effect for group in the case of leg

press scores [$F(2, 46) = 0.028, p = 0.972$]. This meant there were no differences in leg press scores between groups. Mean values for week 0 leg press scores were 149.3 kg for the stability group, 144.6 kg for the movement group, and 145.5 kg for the control. For week 3, mean values for leg press were 157.5 kg for the stability group, 155.7 kg for the movement group and 154.3 for the control. For week 12, mean values for leg press were 166.0 kg for the stability group, 156.8 kg for the movement group and 161.6 kg for the control.

A repeated measures analysis (general linear model) was used to compare both body mass and leg press within each of the groups over the 3 testing times. Separate analyses were used for each dependent variable. For body mass, there was no significant time * group interaction ($p=0.820$, Pillai's Trace). For leg press, there was no significant time * group interaction ($p=0.741$, Pillai's Trace). Atkinson (2001) reported that choosing a specific statistic (Pillai's, Wilk's, etc.) is only important when using the multivariate approach for between-subject factors. In this case, the analysis involved within-subject factors, so the specific statistic chosen was not critical. Pillai's Trace was selected as the test statistic for this analysis. The absence of significant interactions for body mass and leg press (time * group) meant the values for body mass and leg press scores did not differ significantly within groups at any of the 3 testing times, allowing the use of week 0 values as covariates for further analyses.

3.1.3 Vertical Jump Analyses



Graph 3.1 Profile Plot of Vertical Jump Measures

A repeated measures ANCOVA was used to analyze vertical jumps for weeks 3 and 12, using leg press (Newtons), mass (kg) and week 0 jump scores as covariates. These covariates were selected because they were expected to have an influence on vertical jump. These covariates were used to bring everyone to a standard point, to decrease variance within groups. In total, 18 participants' data were used in the stability group, 14 in the movement group, and 14 in the control group.

In repeated measure designs, it is important to test whether the assumption of sphericity is upheld. If not upheld, adjustments have to be made to the alpha value used in any univariate analyses. However, multivariate statistical techniques have the advantage in that they do not assume sphericity and thus make the interpretation of the data analysis easier (Atkinson, 2001). The rule of thumb is that multivariate analyses should not be utilized if the number of subjects is less than 10 more than the number of

repeated measure levels (in the case of the present study, there are 3 levels). In the present study, the sample numbers were far greater than this minimum required sample number, making multivariate analyses appropriate for all data sets.

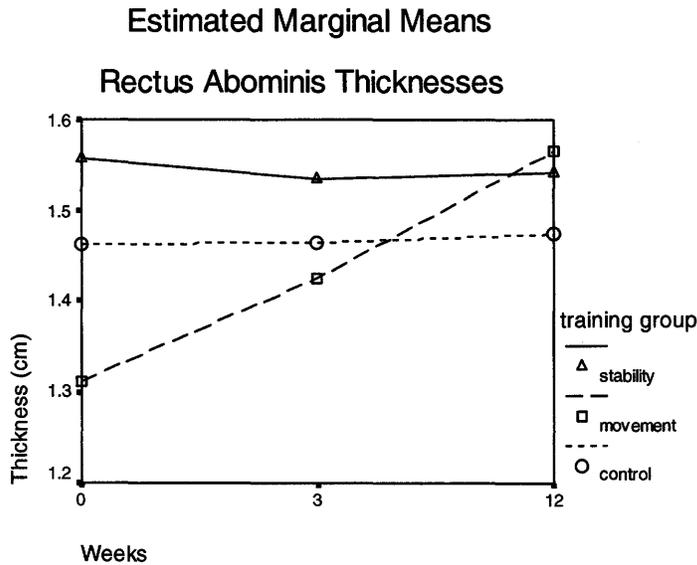
The SPSS multivariate test results (Table 3.2) indicated no significance for the main effect of time nor for the interaction. There were no differences in vertical jump scores among the stability, movement and control groups at either of the measured times. The p values for the covariates were leg press, $p = 0.88$, body mass, $p = 0.88$, and week 0 jump, $p = 0.00$. In hindsight, it is recommended for future analyses that covariates with large p values be excluded from the analysis as they decrease the degrees of freedom in the statistical analysis. At week 3, the mean velocities were 2.20 m/sec for the stability group, 2.13 m/sec for the movement group and 2.34 m/sec for the control. At week 12, the mean velocities were 2.16 m/sec for the stability group, 2.10 m/sec for the movement group and 2.31 m/sec for the control. The analysis also indicated no group effect, which meant there was no significant difference between groups at the measured times [$F(2, 40) = 0.639, p = 0.533$]. The results provided no support for hypothesis 1, Section 1.3.3. As the greatest difference in means was 0.03m/sec, and we defined a meaningful difference as 0.3m/sec for the sample size calculation, there was not a meaningful difference to detect, so power is not reported.

Table 3.2 Multivariate Tests – Vertical Jump

Effect		Value	F	Sig.
TIME	Pillai's Trace	.020	.798	.377
TIME * GROUP	Pillai's Trace	.002	.037	.964

3.1.4 Abdominal Thickness Analyses

3.1.4.1 Rectus Abdominis



Graph 3.2 Profile Plot of Rectus Abdominis Thickness Measures

Rectus abdominis thicknesses were compared for weeks 0, 3 and 12, with body mass (kg) and leg press (Newtons) as covariates. Body mass was selected as a covariate because a larger person is more likely to have larger abdominal muscles. Leg press was selected as a covariate because although there is currently no published literature on the topic, the author believes leg strength may be related to trunk stability, and therefore leg press was at risk for being a confounding variable. The goal of using leg press as a covariate was to therefore decrease the variance in the group. Week 0 scores for muscle thickness were not utilized as covariates in this case because the error in abdominal muscle thickness measures lies in the ultrasound measurement, not in the possibility of the participant learning a task. Seventeen participants' data were used from the stability group, 16 from the movement group, and 14 from the control as described earlier. The SPSS multivariate tests identified no significant main effect for time, but a significant

time * group interaction was found (Table 3.3). There was no main effect for the between subjects effect of group [$F(2, 42) = 0.557, p = 0.577$]. The p values for the covariates were leg press, $p = 0.16$ and body mass, $p = 0.94$. In hindsight, it is recommended for future analyses that covariates with large p values be excluded from the analysis as they decrease the degrees of freedom in the statistical analysis. The power for the time * group interaction was 0.97.

Table 3.3 Multivariate Analyses for Rectus Abdominis Thicknesses

Effect		Value	F	Sig.
Time	Pillai's Trace	.103	2.351	.108
Time * Group	Pillai's Trace	.424	5.657	.000

Post-hoc analyses revealed a significant difference existed in the movement group between weeks 0, 3 and 12 (Table 3.4). To summarize, these results indicated that rectus abdominis was significantly thicker in the movement group at week 3 compared to week 0, and it was again significantly thicker in this group at week 12 when compared to week 3. These results support hypothesis 3, Section 1.3.3, that trunk movement strengthening would result in greater hypertrophy of rectus abdominis than trunk stability training. It is noted, however, that at week 0, the movement group began with a significantly lower mean rectus abdominis thickness than the stability group (Table 3.5). Because the movement group started with a small rectus abdominis thickness, this may account in part for the fact that a significant increase was observed.

3.4 Pairwise Comparisons for Rectus Abdominis Thickness Changes in Movement Group

			Mean Difference (I-J)	Std. Error	Sig.
Training Group	Time	Time			
Stability	1	2	2.107E-02	.036	.564
		3	1.506E-02	.037	.685
	2	1	-2.107E-02	.036	.564
		3	-6.011E-03	.033	.856
	3	1	-1.506E-02	.037	.685
		2	6.011E-03	.033	.856
Movement	1	2	-.113	.037	.004
		3	-.253	.038	.000
	2	1	.113	.037	.004
		3	-.140	.034	.000
	3	1	.253	.038	.000
		2	.140	.034	.000
Control	1	2	-1.786E-03	.040	.964
		3	-1.155E-02	.040	.777
	2	1	1.786E-03	.040	.964
		3	-9.761E-03	.036	.788
	3	1	1.155E-02	.040	.777
		2	9.761E-03	.036	.788

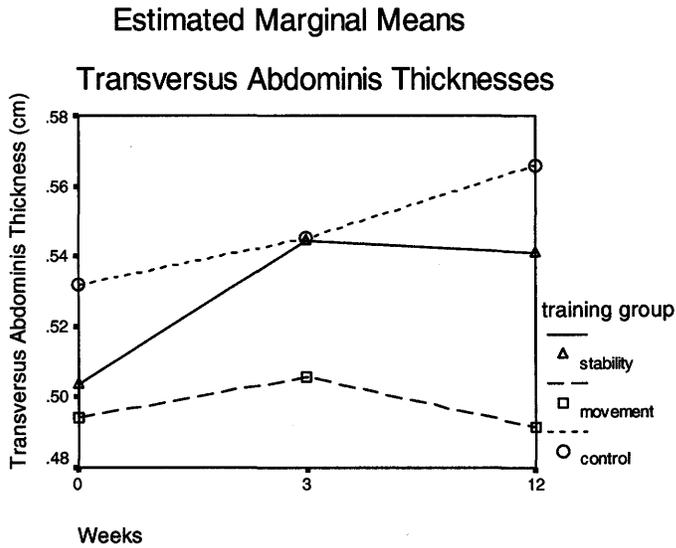
Based on estimated marginal means

Table 3.5 Pairwise Comparisons for Rectus Abdominis – Between Groups

TIME	(I) training group	(J) training group	Mean Difference (I-J)	Std. Error	Sig.(a)
1	stability	movement	.244(*)	.118	.045
		control	9.384E-02	.122	.448
	movement	stability	-.244(*)	.118	.045
		control	-.150	.123	.228
	control	stability	-9.384E-02	.122	.448
		movement	.150	.123	.228
2	stability	movement	.110	.106	.304
		control	7.098E-02	.110	.521
	movement	stability	-.110	.106	.304
		control	-3.904E-02	.110	.725
	control	stability	-7.098E-02	.110	.521
		movement	3.904E-02	.110	.725
3	stability	movement	-2.395E-02	.109	.827
		control	6.723E-02	.113	.555
	movement	stability	2.395E-02	.109	.827
		control	9.118E-02	.113	.425
	control	stability	-6.723E-02	.113	.555
		movement	-9.118E-02	.113	.425

Based on estimated marginal means

3.1.4.2 Transversus Abdominis



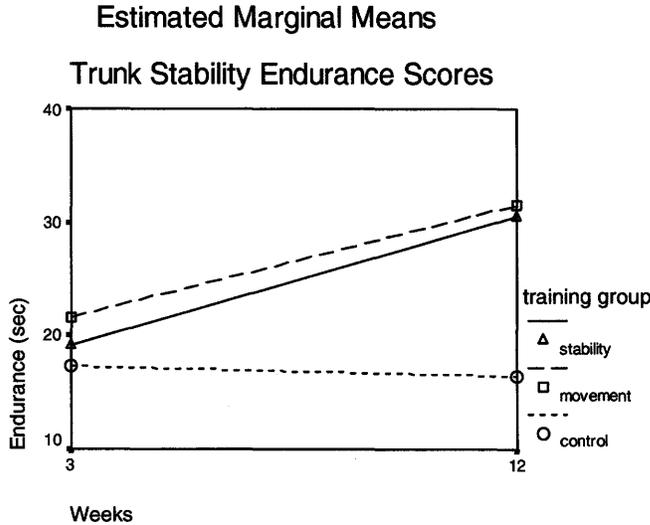
Graph 3.3 – Profile Plot of Transversus Abdominis Thickness Measures

For the transversus abdominis, 17 stability, 16 movement and 14 control participants' data were included in the analyses. The SPSS multivariate analyses revealed no significant main effect for time, and no significant interaction for time * group (Table 3.6). There were no differences in muscle thickness within the stability, movement and control groups at any of the measured times. There was also no group effect [$F(2, 42) = 0.1078, p = 0.350$], indicating no significant difference between groups at the measured times. Covariate p values were leg press, $p = 0.22$ and body mass, $p = 0.04$. Power was 0.25 for the time * group analysis. There was no support for hypothesis 2, Section 1.3.3. Thus, trunk stability training did not result in any greater hypertrophy of transversus abdominis than did training using trunk movement strengthening or than a control.

Table 3.6 Multivariate Analyses for Transversus Abdominis Thicknesses

Effect		Value	F	Sig.
TIME	Pillai's Trace	.026	.539	.587
TIME * GROUP	Pillai's Trace	.076	.825	.513

3.1.4 Trunk Stability Endurance



Graph 3.4 Profile Plot for Endurance Scores

Endurance scores (seconds) were analyzed for weeks 3 and 12, with week 0 used as a covariate. There were 16 participants for each group in this analysis. The multivariate analysis indicated no main effect for time, but there was a significant interaction for time * group (Table 3.7). There was no effect for group [F (2, 44) = 2.155, p = 0.128]. Covariate p value for week 0 endurance was p = 0.02. Power for the time * group interaction was 0.63.

Table 3.7 Multivariate Analyses for Endurance Scores

Effect		Value	F	Sig.
Time	Pillai's Trace	.051	2.350	.132
Time * Group	Pillai's Trace	.139	3.553	.037

Post-hoc pairwise comparisons identified significant differences between stability and control groups at week 12, as well as between the movement and control groups at week 12 (Table 3.8).

Table 3.8 Pairwise Comparisons – Endurance Scores

			Mean Difference (I-J)	Std. Error	Sig.
Time	Training Group	Training Group			
Endurance wk 3	Stability	Movement	-2.498	5.301	.640
		Control	1.833	5.317	.732
	Movement	Stability	2.498	5.301	.640
		Control	4.331	5.439	.430
	Control	Stability	-1.833	5.317	.732
		Movement	-4.331	5.439	.430
Endurance wk 12	Stability	Movement	-1.047	5.589	.852
		Control	14.017	5.607	.016
	Movement	Stability	1.047	5.589	.852
		Control	15.064	5.735	.012
	Control	Stability	-14.017	5.607	.016
		Movement	-15.064	5.735	.012

Based on estimated marginal means

Pairwise comparisons also identified significant differences for both the stability group and the movement group between weeks 3 and 12 (Table 3.9).

Table 3.9 Pairwise Comparisons – Endurance Scores (for groups at each time).

			Mean Difference (I-J)	Std. Error	Sig.
Training Group	TIME	TIME			
Stability	1	2	-11.274	3.451	.002
		2	1	11.274	3.451
Movement	1	2	-9.823	3.505	.008
		2	1	9.823	3.505
Control	1	2	.910	3.512	.797
		2	1	-.910	3.512

Time 1 = week 3, time 2 = week 12

Based on estimated marginal means

In summary, both movement and stability groups' endurance scores improved significantly after 12 weeks. No change was observed for the control group. This did not

support hypothesis 4, Section 1.3.3 which stated that trunk stability training would result in a greater increase in stabilizing endurance of abdominal muscles than trunk movement strengthening.

3.2 Discussion

This study examined the influence of training (trunk stability exercise vs. trunk movement exercise) on vertical jump performance. The primary question was whether trunk stability training produced greater vertical take-off velocity than training using trunk movement strengthening. Also, this study examined two secondary variables, abdominal thickness measures and trunk stability endurance scores. For abdominal thickness, this study examined whether trunk stability training would result in greater hypertrophy of transversus abdominis than that produced by training that incorporated trunk movement strengthening. This study also examined whether trunk movement strengthening would result in greater hypertrophy of rectus abdominis than that produced by trunk stability training. Finally, for trunk stability endurance, the study examined whether trunk stability training would result in greater abdominal muscle stability endurance than that produced by trunk movement strengthening. The researcher chose the two subanalyses to gain a better understanding of the influence of these two physiological variables on vertical jump performance. The secondary variables provided insight into how muscle can change physiologically without influencing performance, which is important when prescribing exercise with performance outcomes in mind.

3.2.1 Vertical Jump

It was determined in this study that vertical take-off velocity did not change after 12 weeks of training using either trunk stability or trunk movement exercises. This result

did not support hypothesis 1, which stated that trunk stability training would result in greater vertical take-off velocity than trunk movement strengthening. Examination of previous literature on vertical jump research identified possible reasons as to why the training of the trunk muscles did not influence the vertical jump performances.

Bobbert and Van Soest (1994) noted that the vertical jump is an explosive movement pattern. They reported that neural feedback, which contributes to control, might not play a major role in controlling the jump. They explained that explosive movements rely on preprogramming; otherwise neural input would take too long and be ineffective in an explosive movement. They emphasized that in order for jumpers to maximize their control, they must practice the jump repeatedly. They explained that if jumpers do not practice after changing the properties of their muscles (for example, thickness and endurance as in the current study), their control would not adjust accordingly with the new properties (Bobbert and Van Soest, 1994). They concluded that without specifically practicing the jump, training the muscles might have no effect on the jump.

Morrissey et al. (1995) reported that static training may be of questionable worth when training for functional performance. They agreed that there was a need for more research in this area. Cordova et al. (1995) reported that although leg strength increased as a result of both isokinetic and isotonic training, there was no change in the reaction force produced by a one-leg jump. They reported that one reason for this lack of change could be a neural factor generally referred to as specificity.

Weiss et al (1999) reported that following strengthening of leg muscles, no change was observed in the vertical jump performance. They concluded that in untrained

men, squat strengthening might not influence explosive types of functional performances. McLaughlin (2001) also reported on specificity of training. McLaughlin (2001) reported that if muscle training does not occur at the speed required in the functional performance, then optimal neurological stimulation may not occur, which could affect the firing patterns, number of fibers activated, and type of fibers activated. Therefore, there may not be carryover to the functional performance. To summarize, the present study did not include jump specific practice or training as a component of the trunk exercise programs. It is possible that this lack of specificity may have resulted in no benefit being gained from abdominal muscle thickening and improved endurance in terms of producing greater vertical take-off velocity.

3.2.2 Abdominal Thickness Measures

The pilot research in the present study agreed with reports by Misuri et al. (1997) that ultrasound measures of abdominal muscle thickness are reliable.

The findings of the 12 week training study revealed that rectus abdominis thickness increased significantly in the movement group from weeks 0 to 3, and again from weeks 3 to 12. However, as noted earlier, rectus abdominis in the movement group was significantly smaller at baseline (week 0) than rectus abdominis in the stability group. The fact that it was smaller to start with may account in part for the fact that it showed significant increases. No significant changes for transversus abdominis were found after 12 weeks of training. For transversus abdominis, there was a trend for improvement in thickness in the stability group after week 3, but this was not significant.

These findings support the hypothesis that training involving trunk movement strengthening will result in greater hypertrophy of rectus abdominis than trunk stability

training. These findings do not support the hypothesis that trunk stability training will result in greater hypertrophy of transversus abdominis muscles than would training that uses trunk movement strengthening. To the best of this author's knowledge, no other research has measured abdominal muscle thicknesses following training. Hemborg et al (1983) found that sit-up strengthening did not lead to permanent increases in intra-abdominal pressure. The present study may lend support to this conclusion. An increase of intra-abdominal pressure producing an extension moment on the spine when transversus abdominis and the oblique abdominals contracted was one of the stability mechanisms discussed (Norris, 1995c). In the present research, although the movement group demonstrated hypertrophy of their rectus abdominis, there was no effect on vertical jump. This may lend support to the Hemborg (1983) conclusion that sit-up strengthening did not lead to permanent increases in intra-abdominal pressure.

Richardson et al. (1999) explained that in a population with lumbar pain, the problem with transversus abdominis is not one of strength or endurance, but instead one of motor control. In the present study, the lack of change of muscle thicknesses in the stability group lends support to the above theory by Richardson et al. (1999) that strength is not a critical factor in the function of transversus abdominis. If strength were a critical component, then hypertrophy would have been expected in a stability group which trained the muscle for 12 weeks. However, the present study population was normal, whereas Richardson et al. (1999) were referring to a population with lumbar pain.

No other research has examined a time course of hypertrophy for the abdominals. The present results suggested that a short time frame is required for significant thickness gains. Specifically, 3 weeks of movement training resulted in rectus abdominis thickness

changes. Rectus abdominis muscle thickness continued to increase during the 12 weeks. Hypertrophy of rectus abdominis is not surprising given the fact that it is composed primarily of type II muscle fibers (Norris, 1995d). MacDougall (1992) indicated in his review of previous research on the area of hypertrophy, that type II fibers exhibit greater relative hypertrophy (from strength training) than type I fibers. Some caution is advised when interpreting the present study results of rectus abdominis thickness increases in the movement group, since in the movement group, rectus abdominis was significantly smaller than the stability group at baseline. This small size at baseline may have accounted for some of the increases noted.

3.2.3 Trunk Stability Endurance

After 12 weeks, both the movement and stability groups' scores showed significant increases compared to the control group. These findings do not support the hypothesis that trunk stability training will result in a greater increase in stabilizing endurance of abdominal muscles than trunk movement strengthening. Instead, both stability and movement groups demonstrated an improved ability to sustain a trunk stability endurance activity after 12 weeks of training.

Richardson et al. (1999) reported that in a population with lumbar pain, the problem with transversus abdominis was not one of strength or endurance, rather it was one of motor control. Hodges (2002) also reported that in training motor control for deep stabilizing muscles in populations with lumbar pain, control and coordination should be the focus instead of strength and endurance.

In contrast, McGill (2001) hypothesized that adequate stability during function was dependant on endurance, not strength of the involved muscles. Evans and Oldreive

(2000) found that golfers with low back pain demonstrated significantly less endurance of transversus abdominis than the group without pain. These findings highlighted endurance as an important concept in the function of transversus abdominis as a stabilizer. The results of the present trunk movement vs. trunk stability study lend support to McGill's hypothesis that endurance is an important factor in trunk stability. When the stability muscles were trained in the present study, the result was increased trunk stabilizing endurance. For the purpose of this study, the term endurance was used to describe the ability to sustain a co-contraction (of the abdominals). The findings also supported McGill's hypothesis that endurance, and not strength, is critical for stability during function. As reviewed in Section 1.2.6 Muscle Strength and Hypertrophy, a well known effect of training for strength is hypertrophy of muscle. No hypertrophy was evident in the stability group, but trunk stabilizing endurance increased.

McGill (1998) defined endurance as the ability to maintain a force for a period of time. It stands to reason that if the transversus abdominis muscle works as a precursor to extremity activity as suggested by Hodges & Richardson (1996 and 1997a), then the requirement to perform this function before every limb movement throughout an entire day would require a certain amount of sustaining ability, or endurance. The ability to sustain a position requires control. In reference to the summary chart in Section 1.2.2 Stability Mechanisms, Panjabi (1992a & b), Lee (1999) and Norris (1995c) all agreed that control played a part in stability. These researchers used the terms neural control subsystem, motor control, and muscle control, respectively. The results from the present study support neural or motor control as an important factor in trunk stability because control was required to sustain or hold the endurance measure position.

McGill (1999) found measures of isometric trunk endurance to be reliable in a normal population. The results of the present pilot study revealed that a measure of trunk endurance can be reliable, even with a different measuring tool than those used by McGill.

The increase in trunk stabilizing endurance of the movement group has not been seen before in the literature. There could be a couple of possible explanations for this finding. The first possibility is that the effect of the movement exercises on internal oblique, which Norris (1995c) defined as a stabilizer, resulted in increased trunk stabilizing endurance. The second possibility is that in addition to the effect on internal oblique, perhaps the technique chosen to measure trunk stabilizing endurance is sensitive to increases in activity of the other movement abdominal muscles (rectus abdominis and external oblique). An EMG study would be required to separate the two possibilities. It would be necessary to determine the levels of activity in the four different abdominal muscles during the sustained double leg lowering activity, before and after training.

3.2.4 General Discussion

Although the movement group demonstrated increased rectus abdominis thickness, as well as increased trunk stabilizing endurance, and the stability group demonstrated increased trunk stabilizing endurance, there was no change by either group in vertical take-off velocity over the 12 week training period. Several reasons may explain this lack of influence of training movement and stability of the trunk on vertical jump. Norris (1995d) discussed specificity of training and reported that in training stability muscles, the exercises must progress to mimicking the speed of the functional requirement. Hodges (2002) also recommended that speed training must be included in

stability exercise. McLaughlin (2001) reported that failing to train at the speed of the functional activity may result in not optimizing firing patterns, number of muscle fibers and type of fibers targeted. She also reported that for training to be optimal, repetition of the exact movement required in the skill should occur. Norris (1995e) also emphasized that when the speed becomes the focus of the training, then the participant must practice the precise functional movements. In summary, the exercises chosen for the present study may not have emphasized the functional movement of a vertical jump enough to produce a change in take-off velocity. The exercises may not have emphasized the specificity of training enough for the vertical jump skill.

The review of literature in Chapter 1 identified control as important for optimizing jumping. In the present study, the trunk stabilizing endurance scores improved for both the trunk movement and trunk stability groups. This meant the ability of the groups to control the positions of their lumbar spines for a period of time improved. These improvements in trunk control did not, however, lead to improved vertical take-off velocities. In addition even though the rectus abdominis muscle thickened, the vertical jump performance did not improve. From these findings, it is evident that training the abdominal muscles in isolation will not influence vertical take-off velocity. The abdominal muscles themselves demonstrated improved thicknesses (in the movement group) and improved trunk stabilizing endurance (in the movement and stability groups), but these factors did not influence the vertical jump performances. This leads one to theorize that training programs for vertical jump must include leg training and plyometrics to be effective in enhancing performance. Skill specific training is

critical in exercise prescription. This philosophy would be applicable in any different jumping sports.

Several situations could have limited the study results. First, there was a large variance in age, abilities and activities of daily living for this normal population. Also, because of the large number of subjects, it was not possible to test people during the exact same time of day or environmental situations (i.e., temperature, quietness of testing area). There was also a limitation inherent in using an untrained population. As Cordova et al. (1995) reported in their study of one-legged jump, the possibility existed that the untrained population did not have the necessary skill set for the jump, perhaps explaining the lack of changes in jump force.

Due to the vast age range (mean age 28.9 years, ranging from 20 – 57 years) and varied skill sets of the participants, this sample may not be representative of a normal population, and therefore it is difficult to generalize the results of this study to a normal population. The results would not be generalizable to people with neck, back or leg pain, heart disease, or a history of training abdominals more than 3 times per week. The study results would not be applicable to people outside the age range. Finally, it would not apply to athletes, who may possess a skill set for jumping that would set them apart from the normal population. The possible reason for this difference has been explained above in reference to Cordova et al. (1995).

According to Thomas and Nelson (2001) external validity is the generalizability of the study results. They cited Campbell and Stanley (1963) regarding four threats to external validity. In the present study these threats are addressed as follows:

1. Pre-test effects – In the case of the present study, pre-testing should not have sensitized the participants to the treatment, as everyone underwent familiarization education.
2. Selection bias – In this study, no special characteristics were targeted in selection, therefore there should have been no bias.
3. Experimental arrangement – All testing occurred in a laboratory, which makes the findings most generalizable to clinical or laboratory settings.
4. Treatment Interference – Only one treatment was given to each group, therefore no effects of multiple treatments would have occurred.

The findings of this study have implications in contributing to the current body of knowledge surrounding vertical jump performance as well as exercise training of the trunk musculature. First, we have identified that training abdominal muscles in isolation did not influence the performance of a vertical jump, regardless of whether the training focused on movement or stability philosophies (the author does not know of any other published literature that has examined this topic). However, we have also noted that due to the large age range and varied skill sets of our sample, the sample may not have been representative of a normal population, which limits the generalizability of the findings. Second, we have identified that stability training did not result in hypertrophy of transversus abdominis in a normal population. This also has not been investigated elsewhere in the literature. Third, we have demonstrated that stability training will enhance trunk stabilizing endurance when a sustained hold of a modified double leg lowering maneuver is used as a measurement technique. Fourth, the results have shown that trunk movement training increased thickness of rectus abdominis as well as

increasing trunk stabilizing endurance (again, the author knows of no published literature examining these variables in reference to trunk movement exercise). The author has acknowledged that the thickness increases in rectus abdominis (in the movement group) may be in part due to the fact that rectus abdominis was significantly smaller at week 0 in the movement group than it was in the stability group.

Chapter 4 Conclusions

4.1 Summary

In general, this study has demonstrated that following a 12 week training program, rectus abdominis thickness increased for the movement group. The possibility was raised that the rectus abdominis thickness increases in the movement group may have been related to the fact that they started significantly smaller than the stability group thicknesses. The stability group showed no thickness changes for transversus abdominis. Both the stability and movement groups demonstrated an increased capacity for trunk stabilizing endurance that was significantly greater than the control group after 12 weeks of training. Despite all of these changes, no changes in vertical take-off velocity were evident in either of the training groups. It is important to understand that vertical jump did not change despite increased thickness of rectus abdominis and increased trunk stabilizing endurance. Due to the absence of skill specific training in the present study, physiological changes in the trunk musculature did not carry over to changes in the functional performance of a vertical jump. In isolation, movement and stability training were shown to be ineffective in increasing the vertical jump performance of the subjects. However, this study does not rule out their influence on jumping performance if functionally specific exercises were trained concurrently.

4.2 Conclusions

Four hypotheses were presented in 1.3.4 Research Hypotheses:

1. Trunk stability training will result in greater vertical take-off velocity than trunk movement strengthening.
2. Trunk stability training will result in greater hypertrophy of transversus abdominis than trunk movement strengthening.

3. Trunk movement strengthening will result in greater hypertrophy of rectus abdominis than trunk stability training.
4. Trunk stability training will result in a greater increase in stabilizing endurance of abdominal muscles than trunk movement strengthening.

The present study provides no support for the first, second and fourth hypotheses. The study provides support for hypothesis three.

4.3 Future Research Suggestions

The present study identified future areas of research that are needed to clarify the role of the abdominal muscles to functional activity. These suggestions include:

1. Increasing the emphasis on more functional movement patterns in the exercises would be a beneficial approach to training. As Norris (1995e) explained, joint angles required in the functional activity should be mimicked when training the stability muscles. Perhaps the present study's training routines were not specific enough, or perhaps the progression of the exercises was too lengthy, not allowing for enough time to be spent on the most difficult final exercises which were designed to be more functional than the initial exercises.
2. Kraemer and Newton (1994) indicated that plyometrics were an excellent way to train jumping skill and muscle coordination. Perhaps future research on the influence of training trunk stability on vertical take-off velocity should involve jumpers co-contracting their transversus abdominis while performing plyometrics and practicing jumping, to increase the likelihood of specificity of training.
3. A different approach would be asking stability and movement trained groups to voluntarily recruit transversus abdominis prior to the jumping test.

4. Insight would be gained from examining EMG findings during vertical jumps to evaluate the involvement of the abdominal muscles during this functional activity. For example, identifying whether transversus abdominis has an anticipatory contraction prior to jump in the way that it contracts prior to limb movement as in the Hodges and Richardson (1996, 1997a & b) studies.
5. Tomioka et al. (2001) reported that knee extension strength and hip-knee coordination contributed significantly but independently to vertical jump height. Their study involved leg muscle strength and coordination. It did not examine the contribution of the trunk to coordination. It may be useful for future research to include trunk control as a variable in a study like the one by Tomioka et al (2001), which utilized forward stepwise regression to determine the variables that best predicted jump height. This would tell us how significantly trunk control influences vertical jump performance.
6. Examining functional activities other than the vertical jump would be an important focus for future research. No other research has examined the effect of stability training on functional performance. In order to thoroughly assess effectiveness of stability training in sport performance and rehabilitation, we must have evidence that stability training is having a positive effect on functional outcomes. Suggested functional activities that could be examined include:
 - time leaving the blocks in a sprinting or speed skating event
 - timed maintenance of optimal balance or position in activities such as synchronized swimming or balance beam gymnastic skills
 - slap shot speed or pitching/throwing speed.

7. Examining functional performance following stability training in a population with low back pain. As described by Hodges and Richardson (1997a & b), abnormalities of transversus abdominis strategy have been identified in people with lumbar pain. Perhaps examining vertical jump following stability training in jumping athletes with lumbar pain would yield different results. Examples of application of this idea might also include athletes with lumbar pain in the sporting events mentioned above. A functional occupational example might be the ability to sustain a forward lean position (from the hips, with a neutral lumbar lordosis) that is sometimes advocated in rehabilitation to avoid sustained lumbar flexion postures. This type of posture is important in activities that are prolonged, in front of a person and at a slightly lower height (for example, working under the hood of a vehicle for a mechanic).
8. In the stability group for the present study, the transversus abdominis contraction was taught to participants. Perhaps in the future, co-contraction with multifidus should be emphasized to see if this partnership would have a different effect on vertical jump than just concentration on transversus abdominis contraction alone. As Hodges (2002) reviewed, multifidus contributes to neutral zone control, stiffness of lumbar segments and control of shear forces.

There is also a future research idea related to abdominal thickness measures. Hides et al. (1996) identified that in a population with lumbar pain, those that received multifidus exercise training recovered the size of multifidus quicker than those that did not receive the training. It would be beneficial to repeat the stability training exercises and measure the abdominals on a population with lumbar pain, to see if transversus abdominis size changes in people with lumbar pain that perform stability training, versus

a group that does not perform the training. Richardson et al. (1999) (whose group included Julie Hides) reviewed the work by Hides et al. (1996a, b & c), stating that it appeared as though multifidus had been retrained to participate in support of the joints. Their opinion was that the same situation likely occurred for transversus abdominis although transversus abdominis had not been measured.

Finally, future research on endurance and stability should focus on finding a more functional measure of endurance. The positions utilized by McGill et al. (1999) and the position used in the present study suited the purposes of the studies but were not ideal functional positions. Improving endurance is important, but to ensure carry over to practical situations, measuring endurance in functional positions would give researchers more information. Finding a better functional position to measure endurance will be difficult, as the position must not include the possibility of leg fatigue, or one could not be sure trunk stability endurance was the only limiting factor.

References

- Abe, T., DeHoyes, D., Pollock, M.L., Garzarella, L. (2000). Time course for strength and muscle thickness changes following upper and lower body resistance training in men and women. *European Journal of Applied Physiology*, 81, 174-180.
- Atkinson, G. (2001). Analysis of repeated measurements in physical therapy research. *Physical Therapy in Sport*, 2, 194-208.
- Augustsson, J., Esko, A., Thomee, R., Svantesson, U. (1998). Weight training of the thigh muscles using closed vs. open kinetic chain exercises: a comparison of performance enhancement. *Journal of Orthopedic and Sports Physical Therapy*, 27 (1), 3-8.
- Ball, T.E., Massey, B.H., Misner, J.E., McKeown, B.C., Lohman, T.G. (1992). The relative contribution of strength and physique to running and jumping performance of boys 7-11. *The Journal of Sports Medicine and Physical Fitness*, 31, 364-371.
- Blackburn, J.R. & Morrissey, M.C. (1998). The relationship between open and closed kinetic chain strength of the lower limb and jumping performance. *Journal of Orthopedic and Sports Physical Therapy*, 6, 430-435.
- Bobbert, M.F., Gerritsen, K.G.M., Litjens, M.C.A. & Van Soest, A. J. (1996). Why is countermovement jump height greater than squat jump height? *Medicine and Science in Sports and Exercise*, 28 (11), 1402-1412.
- Bobbert, M.F. & Van Soest, A. J. (1994). Effects of muscle strengthening on vertical jump height: simulation study. *Medicine and Science in Sports and Exercise*, 26 (8), 1012-1020.
- Butcher, S.J. (2001). *The effect of trunk stability and leg strength training on vertical take-off velocity in athletes*. Unpublished master's thesis, University of Saskatchewan, Saskatoon, Saskatchewan, Canada.
- Campbell, D.T. & Stanley, J.C. (1963). *Experimental and Quasi-experimental Designs for Research*, Chicago: Rand McNally, 5-6.
- Cholewicki, J. & McGill, S.M. (1996). Mechanical stability of the in vivo lumbar spine: implications for injury and chronic low back pain. *Clinical Biomechanics*, 11, 1-15.
- Cissik, J.M. (2002). Programming Abdominal Training, Part I. *Strength and Conditioning Journal*, 24(1), 9-15.

- Cordova, M.L., Ingersoll, C.D., Kovaleski, J.E. & Knight, K.L. (1995). A comparison of isokinetic and isotonic predictions of a functional task. *Journal of Athletic Training*, 30(4), 319-322.
- Craven, B. (Ed.). (2001) *Sport Medicine & Science Council of Saskatchewan Strength and Flexibility Manual*. Saskatoon: University of Saskatchewan Printing Services.
- Crisco, J.J. & Panjabi, M.M. (1992). Euler stability of the human ligamentous lumbar spine. Part I, theory. *Clinical Biomechanics*, 7, 19-26.
- Crisco, J.J., Panjabi, M.M., Yamamoto, I. & Oxland, T.R. (1992). Euler stability of the human ligamentous lumbar spine. Part II, experiment. *Clinical Biomechanics*, 7, 27-32.
- Cureton, K.J., Collins, M.A., Hill, D.W., & McElhannon, F.M. Jr. (1988). Muscle hypertrophy in men and women. *Medicine and Science in Sports and Exercise*, 20, 338-344.
- Davies, J., Parker, D.F., Rutherford, O.M. & Jones, D.A. (1988). Changes in strength and cross-sectional area of the elbow flexor as a result of isometric strength training. *European Journal of Applied Physiology*, 57, 667-670.
- Dowling, J.J. & Vamos, L. (1993). Identification of kinetic and temporal factors related to vertical jump performance. *Journal of Applied Biomechanics*, 9, 95-110.
- Elliot, J.M. and Zylstra, E.D. (2002). Real-time ultrasound imaging and the physiotherapist: a review. *Orthopedic Division Review, Diagnostic Imaging and Physiotherapy*, Canadian Physiotherapy Orthopaedic Division.
- Enoka, R.M. (1994). The motor system. In *Neuromechanical Basis of Kinesiology* (2nd ed.) (pp.241). Windsor, ON: Human Kinetics.
- Evans, C. & Oldreive, W. (2000). A study to investigate whether golfers with a history of low back pain show a reduced endurance of transverses abdominis. *The Journal of Manual & Manipulative Therapy*, 8 (4), 162-174.
- Farthing J.P. & Chilibeck, P.D. (2003). The effects of eccentric and concentric training at different velocities on muscle hypertrophy. *European Journal of Applied Physiology*, 89 (6), 578-586.
- Feltner, M.E., Frascetti, D.J. & Crisp, R.J. (1999). Upper extremity augmentation of lower extremity kinetics during countermovement vertical jumps. *Journal of Sports Sciences*, 17, 449-466.

- Fleisig, G.S., Jameson, E.G., Dillman, C.J. & Andrews, J.R. (2000). Biomechanics of Overhead Sports. In W.E. Garrett, Jr. & D.T. Kirkendall (Eds.), *Exercise and Sport Science* (pp. 563-584). Philadelphia: Lippincott Williams & Wilkins.
- Gibbons, S.G.T. & Comerford, M. (2001). Strength versus stability part I: concept and terms. *Orthopaedic Division Review*, March/April, 21-27.
- Hagins, M., Adler, K., Cash, M., Daugherty, J., & Mitrani, G. (1999). Effects of practice on the ability to perform lumbar stabilization exercises. *Journal of Orthopaedic & Sports Physical Therapy*, 29(9), 546-555.
- Hakkinen, K. (1989). Neuromuscular and hormonal adaptations during strength and power training. *The Journal of Sports Medicine and Physical Fitness*. 29 (1), 9-26.
- Hakkinen, K. & Komi, P.V. (1985). Effect of explosive type strength training on electromyographic and force production characteristics of leg extensor muscles during concentric and various stretch-shortening cycle exercises. *Scandinavian Journal of Sports Science*, 7 (2), 65-76.
- Hashimoto, B.E., Kraemer, D.J., Wiitala, L. (1999). Applications of Musculoskeletal Sonography. *Journal of Clinical Ultrasound*, 27, 293-318.
- Hemborg, B., Moritz, U, & Hamberg, J. (1983). Intra-abdominal pressure and trunk muscle activity during lifting – effect of abdominal muscle training in healthy subjects. *Scandinavian Journal of Rehabilitation Medicine*, 15, 183-196.
- Hides, J.A. (1996a). *Multifidus muscle recovery in acute low back patients*. PhD thesis, Department of Physiotherapy, The University of Queensland.
- Hides, J. A., Richardson, C.A., Jull, G.A. (1995a). Magnetic resonance imaging and ultrasonography of the lumbar multifidus muscle. Comparison of two different modalities. *Spine*, 20(1), 54-58.
- Hides, J.A., Richardson, C.A., Jull, G.A., Davies, S. (1995b). Ultrasound imaging in rehabilitation. *Australian Physiotherapy*, 41(3), 187-193.
- Hides, J.A., Richardson, C.A. and Jull, G.W. (1996b). Multifidus muscle recovery is not automatic after resolution of acute, first-episode low back pain. *Spine*, 21(23), 2763-2769.
- Hides, J.A., Richardson, C.A. & Jull, G.W. (1996c). Multifidus muscle rehabilitation decreases recurrence of symptoms following first episode low back pain. In: *Proceedings of the National Congress of the Australian Physiotherapy Association*, Brisbane.

- Hides, J.A., Richardson, C.A. and Jull, G.W. (1998). Use of real-time ultrasound imaging for feedback in rehabilitation. *Manual Therapy*, 3(3), 125-131.
- Hodges, P.W. & Richardson, C.A. (1996). Inefficient muscular stabilization of the lumbar spine associated with low back pain, a motor control evaluation of transverses abdominis. *Spine*, 21 (22) 2640-2650.
- Hodges, P.W. & Richardson, C.A. (1997 a). Contraction of the abdominal muscles associated with movement of the lower limb. *Physical Therapy*, 77 (2), 132-144.
- Hodges, P.W. & Richardson, C.A. (1997 b). Relationship between limb movement speed and associated contraction of the trunk muscles. *Ergonomics*, 40 (11), 1220-1230.
- Hodges, P.W. & Richardson, C.A. (1998). Delayed postural contraction of transversus abdominis in low back pain associated with movement of the lower limb. *Journal of Spinal Disorders*, 11 (1), 46-56.
- Hodges, P.W. & Richardson, C.A. (1999). Transversus abdominis and the superficial abdominal muscles are controlled independently in a postural task. *Neuroscience Letters*, 265, 91-94.
- Hoeger, W.K & Hoeger, S.A. (2002). *Principles and Labs for Physical Fitness* (3rd ed.). Canada: Wadsworth/Thomson Learning.
- Hubley, C.L. & Wells, R.P. (1983). A work-energy approach to determine individual joint contributions to vertical jump performance. *European Journal of Applied Physiology*, 50, 247-254.
- Jull, G.A. & Richardson, C.A. (1994). Rehabilitation of active stabilization of the lumbar spine. In L.T. Twomey & J.R. Taylor (Eds.), *Clinics in Physical Therapy, Physical Therapy of the Low Back* (2nd ed.) (pp. 251-273). New York: Churchill Livingstone, Inc.
- Jull, G.A. & Richardson, C.A. (2000). Motor control problems in patients with spinal pain: a new direction for therapeutic exercise. *Journal of Manipulative and Physiological Therapeutics*, 23 (2), 115-117.
- Kraemer, W.J. & Newton, R.U. (1994). Training for improved vertical jump. *Sports Science Exchange*, 7 (6), 1-13. Retrieved April 27, 2003 from <http://www.gssiweb.com>.
- Lee, D. (1999). Impaired load transfer through the pelvic girdle secondary to altered neutral zone function. *Orthopaedic Division Review*, Jan/Feb, 19-23.
- Lemaire, S. (1999). *Physigraphe Clipart* (1st ed.). Quebec: Physigraphe Inc.

- Le Pellec, A. & Maton, B. (2002). Initiation of a vertical jump: the human body's upward propulsion depends on control of forward equilibrium. *Neuroscience Letters*, 323 (3), 183-186.
- Levangie, P.K and Norkin, C.C. (2001). *Joint Structure and Function: A Comprehensive Analysis* (3rd ed.). Philadelphia: F.A. Davis Company.
- Luhtanen, P. & Komi, P.V. (1978). Segmental contribution to forces in vertical jump. *European Journal of Applied Physiology*, 38, 181-188.
- MacDougall, J.D. (1992). Hypertrophy or Hyperplasia. In P.V. Komi (Ed.), *Strength and Power in Sport* (pp. 230-238). Windsor: Human Kinetics.
- MacDougall, J.D., Gibala, M.J., Tarnopolsky, N.A., MacDonald, J.R., Interisano, S.A. & Yarasheski, R.E. (1995). The time course for elevated muscle protein synthesis following heavy resistance exercise. *Canadian Journal of Applied Physiology*, 20, 480-486.
- McArdle, W.D., Katch, F.I. & Katch, V.L. (1991). *Exercise Physiology, Energy, Nutrition and Human Performance* (3rd Ed.). Philadelphia: Lea and Febiger, 384-417.
- McGill, S.M. (1998). Low back exercises: evidence for improving exercise regimens. *Physical Therapy*, 78(7), 754-765.
- McGill, S.M. (2001). Low back stability: from formal description to issues for performance and rehabilitation. *Exercise and Sport Sciences Reviews*, 29 (1), 26-31.
- McGill, S.M., Childs, A. & Liebenson, C. (1999). Endurance times for low back stabilization exercises: clinical targets for testing and training from a normal database. *Archives of Physical Medicine and Rehabilitation*, 80, 941-944.
- McGill, S.M. & Cholewicki, J. (2001). Biomechanical basis for stability: an explanation to enhance clinical utility. *Journal of Orthopaedic & Sports Physical Therapy*, 31 (2), 96-100.
- McLaughlin, E.J. (2001). A comparison between two training programs and their effects on fatigue rates in women. *Journal of Strength and Conditioning Research*, 15(1), 25-29.
- Miller, T.A., White, E.D., Kinley, K.A., Congleton, J.J., & Clark, M.J. (2002). The effects of training history, player position, and body composition on exercise

- performance in collegiate football players. *Journal of Strength and Conditioning Research*, 16 (1), 44-49.
- Misuri, G., Colagrande, S., Gorini, M., Iandelli, I., Mancini, M., Duranti, R., Scano, G. (1997). In vivo ultrasound assessment of respiratory function of abdominal muscles in normal subjects. *European Respiratory Journal*, 10, 2861-2867.
- Morrisey, M.C., Harman, E.A. & Johnson, M.J. (1995). Resistance training modes: specificity and effectiveness. *Medicine and Science in Sports and Exercise*, 27(5), 648-660.
- Nagano, A. & Gerritsen, K.G.M. (2001). Effects of neuromuscular strength training on vertical jumping performance – a computer simulation study. *Journal of Applied Biomechanics*, 17 (2), 113-128.
- Nigg, B.M., Stefanyshyn, D. & Denoth, J. (2000). Mechanical Considerations of Work and Energy. In Nigg, B.M., MacIntosh, B.R & Mester, J. *Biomechanics and Biology of Movement*, (pp.5-18). Windsor: Human Kinetics.
- Norris, C. M. (1995a). Active lumbar stabilization – concepts. *Physiotherapy*, 81(2), 61-64.
- Norris, C. M. (1995b). Stabilisation mechanisms of the lumbar spine. *Physiotherapy*, 81(2), 72-79.
- Norris, C.M. (1995c). Limiting factors to end-range motion in the lumbar spine. *Physiotherapy*, 81(2), 64-72.
- Norris, C. M. (1995d). Muscle imbalance and the low back. *Physiotherapy*, 81 (3), 127-138.
- Norris, C. M. (1995e). An exercise program to enhance lumbar stabilization. *Physiotherapy*, 81(3), 138-146.
- O'Sullivan, P.B., Twomey, L., Allison, G.T. (1998). Altered abdominal muscle recruitment in patients with chronic back pain following a specific exercise intervention. *Journal of Orthopedic and Sports Physical Therapy*, 27, 114-124.
- Panjabi, M.M. (1992a). The stabilizing system of the spine. Part 1. Function, dysfunction, adaptation, and enhancement. *Journal of Spinal Disorders*, 5 (4), 383-389.
- Panjabi, M.M. (1992b). The stabilizing system of the spine. Part II. Neutral Zone and Instability Hypothesis. *Journal of Spinal Disorders*, 5 (4), 390-397.

- Pearsall, J. (Ed.). (2001). *The Concise Oxford Dictionary (10th Ed.)*. Oxford: Oxford University Press.
- Pool-Goudzwaard, A.L., Vleeming, A. Stoeckart, R., Snijders, D.J., & Mens, J.M.A. (1998). Insufficient lumbopelvic stability: a clinical, anatomical and biomechanical approach to “a-specific” low back pain. *Manual Therapy*, 3 (1), 12-20.
- Richardson, C.A. & Jull, G.A. (1995). Muscle control – pain control. What exercises would you prescribe? *Manual Therapy*, 1, 2-10.
- Richardson, C.S., Jull, G.S., Hodges, P.W. & Hides, J.A. (1999). *Therapeutic Exercise for Spinal Segmental Stabilization in Low Back Pain, Scientific Basis and Clinical Approach*, United Kingdom: Churchill Livingstone.
- Richardson, C.S., Jull, G.S., Toppenberg, R.M.K. & Comerford, M.J. (1990). New perspectives in lumbar spine stabilization prior to exercise. *Proceedings of the 27th National Annual Scientific Conference of the Australian Sports Medicine Federation*.
- Richardson, C.A., Snijders, C.J., Hides, J.S., Damen, L., Pas, M.S. and Storm, J. (2002). The relation between the transversus abdominis muscles, sacroiliac joint mechanics, and low back pain. *Spine*, 27(4), 399-403.
- Robertson, D.G.E. & Fleming, D. (1987). Kinetics of standing broad and vertical jumping. *Canadian Journal of Sport Sciences*, 12 (1), 19-23.
- Sahrmann, S.A. (2002). *Diagnosis and Treatment of Movement Impairment Syndromes*. St. Louis, Mosby, Inc.
- Semenick, D.M. & Adams, K.O. (1987). The vertical jump: a kinesiological analysis with recommendations for strength and conditioning programming. *National Strength and Conditioning Association Journal*, 9 (3), 5-9.
- Sipila, S. & Suominen, H. (1993). Muscle ultrasonography and computed tomography in elderly trained and untrained women. *Muscle Nerve*, 16, 294-300.
- Sipila, S. & Suominen, H. (1996). Quantitative ultrasonography of muscle: detection of adaptations to training in elderly women. *Archives of Physical medicine and Rehabilitation*, 77, 1173-1178.
- Sparto, P.J., Parnianpour, M., Reinsel, T.E. & Simon, S. (1997). The effect of fatigue on multijoint kinematics, coordination and postural stability during a repetitive lifting test. *Journal of Sport Physical Therapy*, 25 (1), 3-12.

- Stokes, M. & Young, A. (1986). Measurement of quadriceps cross-sectional area by ultrasonography: A description of the technique and its application in physiotherapy. *Physiotherapy Theory and Practice*, 2, 31-36.
- Tant, C.L., Lamack, D. & Greene, B. (1993). A biomechanical and physiological analysis of the volleyball jump set. *National Strength and Conditioning Association Journal*, 15 (4), 25-30.
- Tittel, K & Wutscherk, H. (1992). Anthropometric Factors. In P.V. Komi (Ed.), *Strength and Power in Sport* (pp.180-196). Windsor: Human Kinetics.
- Thomas, J.R & Nelson, J.K. (2001). *Research Methods in Physical Activity* (4th ed.). Illinois: Human Kinetics.
- Tomioka, M., Owings, T.M & Grabiner, M.D. (2001). Lower Extremity Strength and Coordination are Independent Contributors to Maximum Vertical Jump Height. *Journal of Applied Biomechanics*, 17, 181-187.
- Vincent, W.J. (1999). *Statistics in Kinesiology* (2nd ed.). Windsor: Human Kinetics.
- Ware, J.S., Clemens, C.T., Mayhew, J.L. & Johnston, T.J. (1995). Muscular endurance repetitions to predict bench press and squat strength in college football players. *Journal of Strength and Conditioning Research*, 9, 99-103.
- Weiss, L.W., Coney, H.D. & Clark, F.C. (1999). Differential functional adaptations to short-term low-, moderate-, and high-repetition weight training. *Journal of Strength and Conditioning Research*, 13(3), 236-241.
- Wohlfahrt, D., Jull, G., Richardson, C. (1993). The relationship between the dynamic and static function of abdominal muscles. *Australian Physiotherapy*, 39(1), 9-12.
- Zanotti, C.M., Bohannon, R.W., Tiberio, D., Dewberry, M.J. & Murray, R. (2002). Kinematics of the double-leg-lowering test for abdominal muscle strength. *Journal of Orthopaedic & Sports Physical Therapy*, 32, 432-436.

Appendices

Appendix A

Information Letter to Participants and Consent Form

May, 2002

Dear Eager Participant:

We appreciate your willingness to participate in our research study!! The study is entitled, “A Comparison of the Effect of Trunk Stability and Trunk Movement Strengthening on Vertical Take-off Velocity”. The researchers are Stacey Lovo, B.Sc.P.T., Dr. Eric Sprigings, Ph. D., and Bruce Craven, M. Sc., from the College of Kinesiology at the University of Saskatchewan. The research study is for Stacey’s Master’s thesis.

The purpose of the study is to find out the best way to train for improving jumping speed and height, to determine the effect of two training methods on stomach muscle size, strength and endurance. The two training methods are trunk stability and trunk movement strengthening. Stability training involves exercising with the spine held in a neutral position. Movement training involves exercising with the spine moving. A control group will perform stretching exercises for the duration of the program. The training occurs three times per week, for about thirty minutes per session, for twelve weeks. One of these sessions is performed at the College of Kinesiology with Stacey Lovo, so she can monitor and progress your exercises, and look at your activity diary. The control group will be contacted at their homes once every two weeks. They are not required to attend the weekly sessions; they only need to attend the three testing sessions.

At weeks 0, 3 and 12, testing will occur. Muscle ultrasound and will be used to take pictures of the abdominal muscles. You will perform a leg press test to determine

leg strength, leg lowering maneuvers to determine strength and endurance of stability muscles, and jump from a platform to determine your jumping speed.

Although they are not guaranteed, possible benefits of participation include improved strength and tone of abdominal muscles, improved posture, and improved training methods for sports that involve jumping.

All information gathered for the study will be kept confidential and stored in a locked cabinet. Only the researchers listed above will have access to the data.

With exercise there is always the risk of back, stomach and leg soreness and injury. The researchers will give you instructions about exercise clothing as well as pre and post-exercise stretches, and they will tell you what to do in case of injury to make the possibility of these risks lower.

Participation is voluntary. You can withdraw from the study at any time without penalty or unfair treatment.

Sincerely,

Stacey Lovo

Dr. Eric Sprigings

Bruce Craven

Consent Form

Title of the study: A Comparison of the Effect of Trunk Stability and Trunk Movement Strengthening on Vertical Take-off Velocity

Names of Researchers:

Stacey Lovo, B.Sc.P.T., College of Kinesiology, University of Saskatchewan ()
Eric Sprigings, Ph.D. College of Kinesiology, University of Saskatchewan (966-6500)
Bruce Craven, B.Sc.P.T., M.Sc., College of Kinesiology, University of Saskatchewan (966-6514)

Purpose of the research: The purpose is to determine the effectiveness of trunk stability training or trunk movement training for improving jumping ability. The effect of the training on jump velocity as well as endurance and strength of abdominal muscles will be measured. The influence of these training regimes on abdominal muscle thickness will also be examined.

Possible Benefits: If you are in the exercise training groups, your abdominal muscular endurance, strength and vertical jumping ability may improve during the study. These benefits are not guaranteed.

Procedures: You will be initially randomised to one of three groups: 1) A group that will take part in 12 weeks of static training, where you will train your abdominal muscles while not moving your spine (stability training); 2) A group that will take part in 12 weeks of dynamic training, where you will train your abdominal muscles while moving the spine; 3) a non-training control group that performs only stretching exercises. You will have an equal chance of being assigned to each group.

Subjects in the training groups will train for 30 minutes each session, 3 days per week, for 12 weeks. Subjects in Group 1 will perform stability exercises (i.e. static exercises) of the abdominal muscles, while subjects in Group 2 will perform dynamic exercises (i.e. exercises that involve more movement) of the abdominal muscles. Two exercise sessions per week will be performed at home and one exercise session per week will be performed at the College of Kinesiology. Subjects will keep a log of their exercises. Controls will keep a log of their usual activity.

Subjects in the non-exercising control group will do their stretches twice a day, three times per week. They will be telephoned every 2nd week to be asked about their exercise activities.

You will be required to perform exercise tests (irrespective of group assignment) before the training, after 3 weeks, and after 12 weeks. Strength and endurance of your abdominal muscles, and your vertical jumping ability will be tested. The thickness of your abdominal muscles will also be measured by ultrasound.

Risks: There is a risk of muscle or joint injury during the exercise training and testing. Proper warm-up prior to exercise or testing should minimise this risk. There may be unforeseen risks associated with the study. If you are injured during any part of the study, we will provide necessary medical treatment/therapy for that injury.

Alternatives to the Exercise Program: Other exercise programs exist for improving your vertical jump. This includes strength and power training. Other exercise programs, aside from that in this study, are available for improving abdominal muscular endurance and strength. We will provide information on these programs if you wish. We will ask you to refrain from these programs if you are taking part in this study.

Withdrawal from the Study: You are free to withdraw from the study at any time. This withdrawal will not affect your academic status or access to any health or other services.

Confidentiality: Precautions will be taken to protect your anonymity including secure storage of any data collected. The data we collect from this study will be used in a master's thesis and perhaps journal articles, but only aggregate data will be reported and you will be unidentifiable.

Contact Numbers: If you have any questions with regard to the research project, please call Stacey Lovo (), Dr. Eric Sprigings (966-6481), or Bruce Craven (966-6514).

If you have any questions concerning your rights as a research subject, you may contact the Office of Research Services at the University of Saskatchewan at 966-4053.

Throughout the study, we will advise you of any new information that may have a bearing on your decision to continue in the study.

You will receive feedback on your results throughout the study.

By signing below, you acknowledge that the study and contents of this consent have been explained to you, that you understand the contents, and that you have received a copy of the consent form for your own records. By signing this consent form, you do not waive any of your rights as a research subject. Signing this consent form does not release the investigators from liability for negligence.

Participant's signature: _____

Date: _____

Researcher's signature: _____

Date: _____

Witness: _____

Date: _____

Appendix B

Pre-testing Questionnaire and Check for Exclusion Criteria

Pre Test Restrictions (Butcher, 2001)

Please follow these restrictions in order to help obtain the most accurate measurements possible. Your cooperation will help provide the best scientific results possible and is appreciated.

1. Do not lift weights closer than 24 hours prior to your testing time.
2. Do not eat for 4 hours prior to testing time.
3. Do not consume caffeine and do not smoke the day of testing.
4. Do not drink alcohol closer than 24 hours prior to your testing time.
5. Be prepared to give full effort during testing.

Thank you for volunteering.

Signature: _____

Date: _____

Pre-Testing Questionnaire and Check for Exclusion Criteria

Name: _____ Male/Female

Age: _____ Date of Birth: _____

Weight: _____ Height: _____

Calculated BMI: kg/m²: _____ (will be calculated by researcher)

Phone: _____ Email: _____

Address:

Presence of heart disease: _____

Presence of neck, back or leg pain: _____

Presence of current abdominal training greater than 3 times per week: _____

Appendix C
Activity Diary

Activity Diary – Please indicate the days that you did your exercises or attended a check-in session. You will need to bring this to check-in sessions and turn it in at the completion of the 12 week program. Name: _____

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Week 1							
Week 2							
Week 3							
Week 4							
Week 5							
Week 6							
Week 7							
Week 8							
Week 9							
Week 10							
Week 11							
Week 12							

Appendix D
Exercise Programs

Control Group Exercise Program

Safety and Stretching

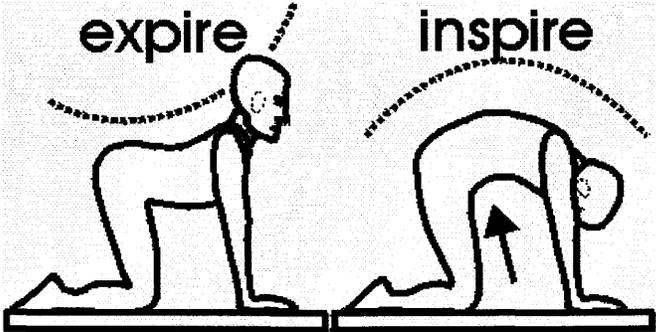
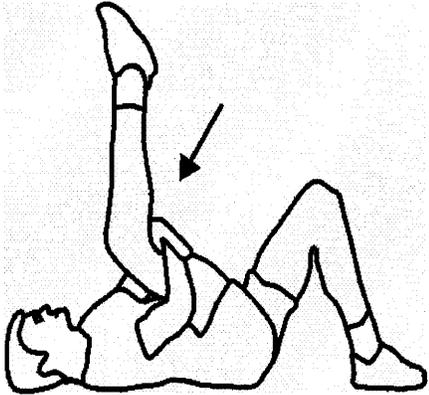
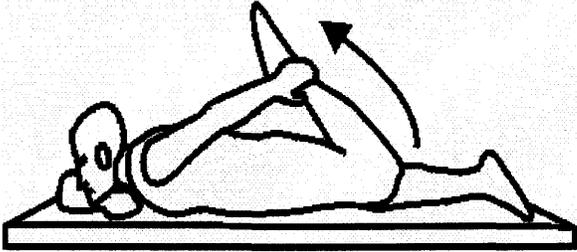
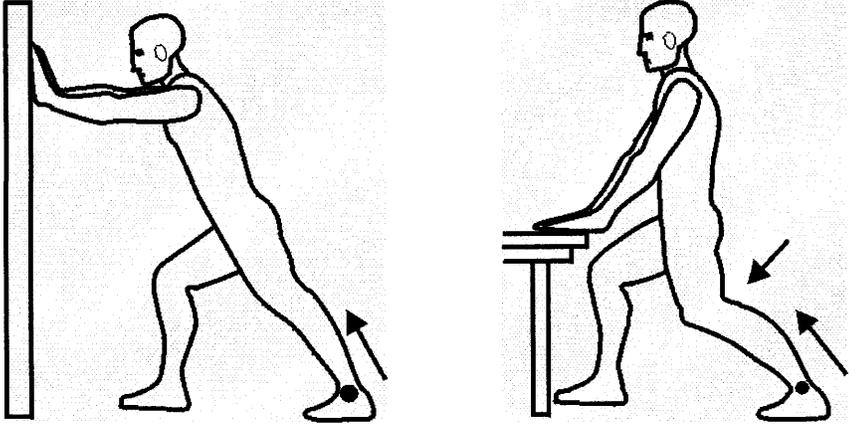
It is recommended that all stretching is done in properly fitting exercise clothing and shoes. Stretching of your back, quadriceps, hamstrings and calf muscles is recommended.

If injury occurs due to stretching, the following procedures are recommended:

1. Stop the stretching.
2. Ice the affected body part for 10 minutes, up to every two hours, for three consecutive days.
3. Inform Stacey Lovo (at) that you have had an injury.
4. Rest the affected body part.
5. If your symptoms of discomfort last greater than three days, you should see a medical doctor for evaluation.

The following are your recommended stretches:

For the first 4 pictures, hold each position as instructed for 30 seconds. Repeat 2 times for each leg. For the fourth picture, repeat 5 times. Do these stretches before and after the training exercises (stretches from Physiograph software).



Movement and Stability Groups

Safety and Exercise

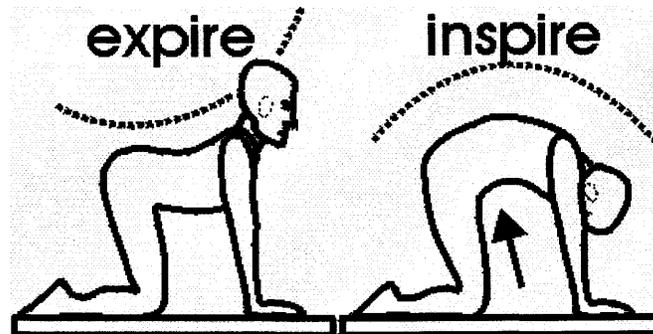
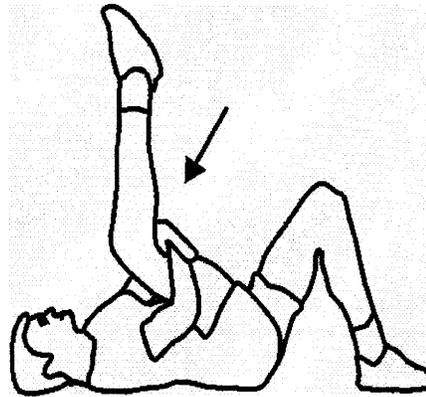
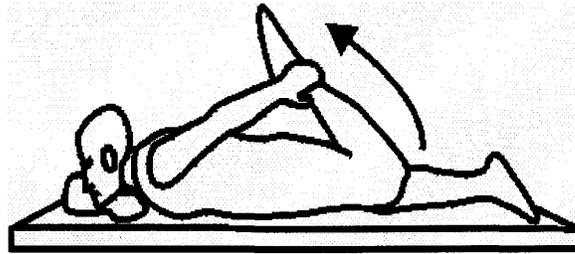
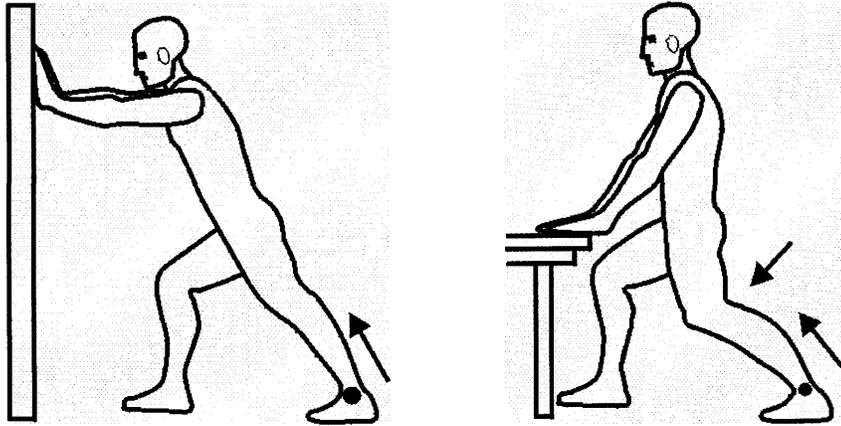
Muscle strengthening involves risks like discomfort and injury. It is recommended that all exercise is done in properly fitting exercise clothing and shoes. Stretching of your back, quadriceps, hamstrings and calf muscles before and after exercise is recommended.

If injury occurs due to exercise, the following procedures are recommended:

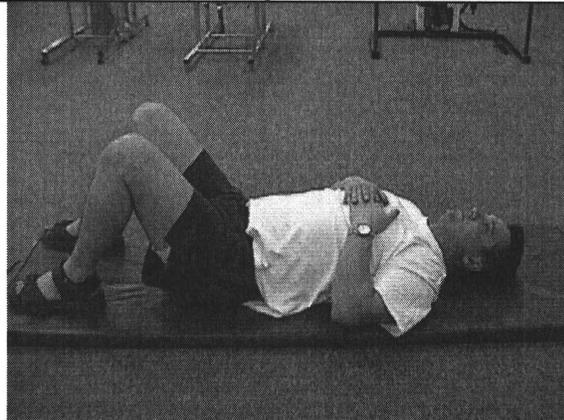
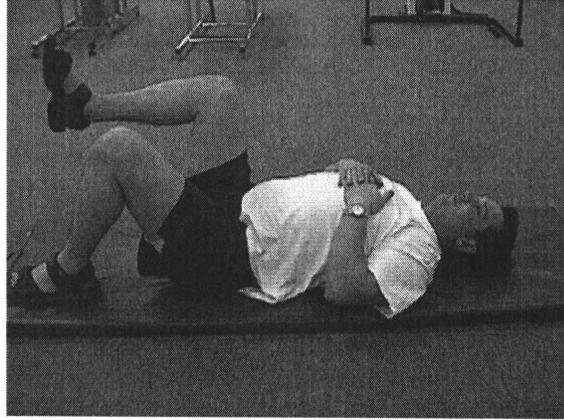
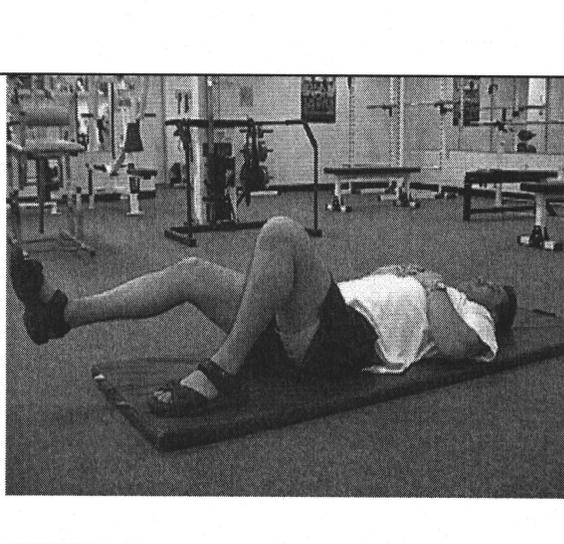
1. Stop the exercise.
2. Ice the affected body part for 10 minutes, up to every two hours, for three consecutive days.
3. Inform Stacey Lovo (at _____) that you have had an injury.
4. Rest the affected body part.
5. If your symptoms of discomfort last greater than three days, you should see a medical doctor for evaluation.

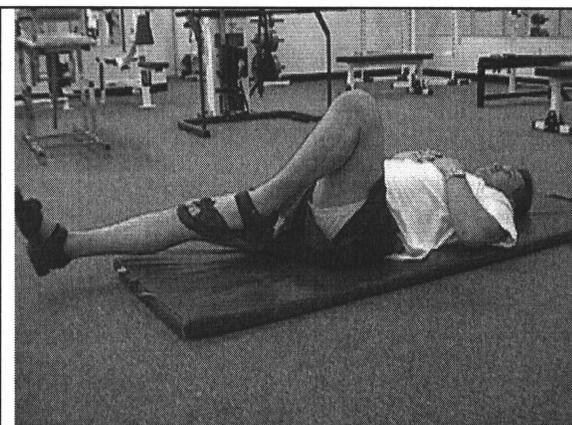
The following are your recommended pre and post-exercise stretches:

For the first 4 pictures, hold each position as instructed for 30 seconds. Repeat 2 times for each leg. For the fourth picture, repeat 5 times. Do these stretches before and after the training exercises (stretches from Physiograph software).



Stability Group Exercise Program
Trunk Stability - Sagittal Flexion Plane

	<p>Abdominal cocontract - pull your belly button in toward your spine.</p> <p>_____hold 5 seconds _____hold 8 seconds _____hold 10 seconds _____do 5 reps _____do 8 reps _____do 10 reps</p> <p>Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.</p>
	<p>Raise one knee up to 90 degrees, then abdominal cocontract (pull your belly button in toward your spine). While holding the contraction, lower the leg back to the starting position. Repeat with the other leg</p> <p>_____hold 5 seconds (take 5 seconds to lower leg) _____hold 8 seconds _____hold 10 seconds _____do 5 reps per leg _____do 8 reps per leg _____do 10 reps per leg</p> <p>Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.</p>
	<p>Abdominal cocontract - pull your belly button in toward your spine. While holding, straighten one leg to the floor, raise it back up to starting position, and repeat with the other leg.</p> <p>_____hold 5 seconds (take 5 seconds to lower leg) _____hold 8 seconds _____hold 10 seconds _____do 5 reps _____do 8 reps _____do 10 reps</p> <p>Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.</p>



Lift one knee up to 90 degrees. Abdominal cocontract - pull your belly button in toward your spine. Hold that knee at 90 degrees while lowering the other leg to the floor.

_____hold 5 seconds (5 seconds to perform the lowering)

_____hold 8 seconds

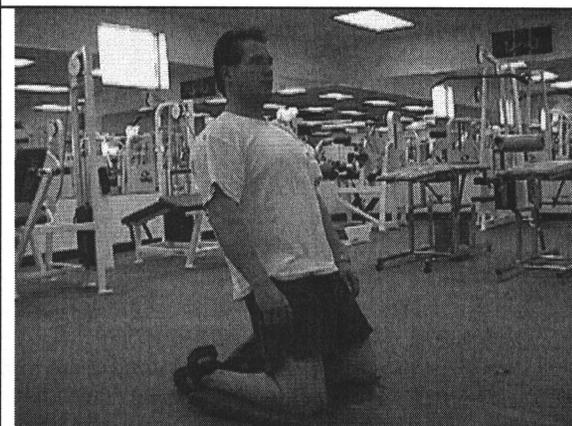
_____hold 10 seconds

_____do 5 reps per leg

_____do 8 reps

_____do 10 reps

Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.



Abdominal cocontract - pull your belly button in toward your spine. While maintaining this position, lean back 45 degrees. Then return to start (neutral).

_____hold 5 seconds

_____hold 8 seconds

_____hold 10 seconds

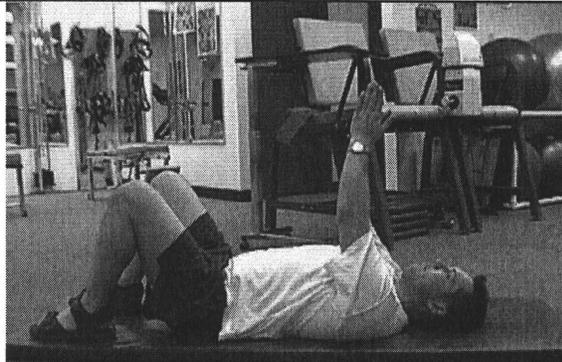
_____do 5 reps

_____do 8 reps

_____do 10 reps

Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.

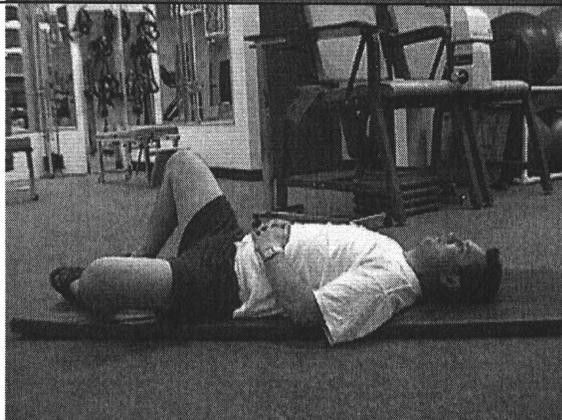
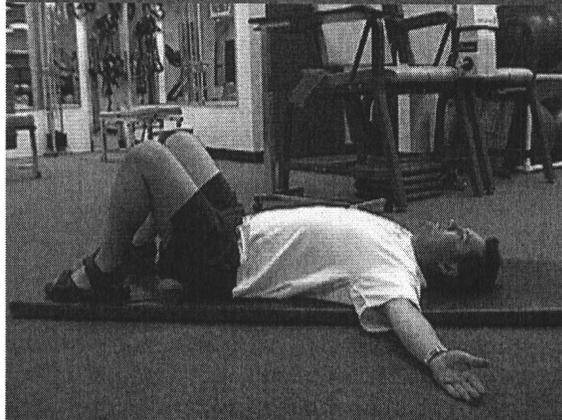
Trunk Stability – Transverse Plane



Begin with both hands together above your chest. Abdominal cocontract, and lower hands out to your sides (while maintaining the cocontraction).

- _____ hold 5 seconds (at the end of the motion)
- _____ hold 8 seconds
- _____ hold 10 seconds
- _____ do 5 reps per arm
- _____ do 8 reps
- _____ do 10 reps

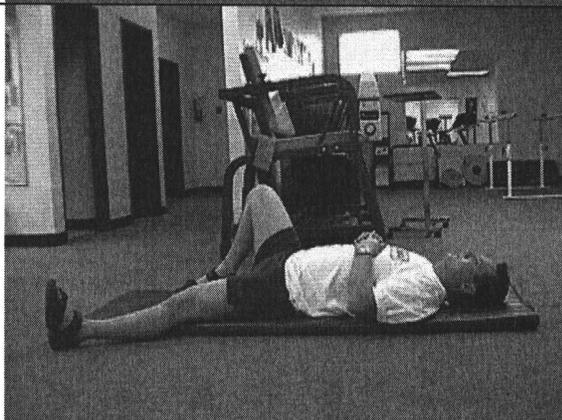
Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.



Begin with knees bent up. Abdominal cocontract, and drop bent knee out to the side.

- _____ hold 5 seconds (at the end of the motion)
- _____ hold 8 seconds
- _____ hold 10 seconds
- _____ do 5 reps per arm
- _____ do 8 reps
- _____ do 10 reps

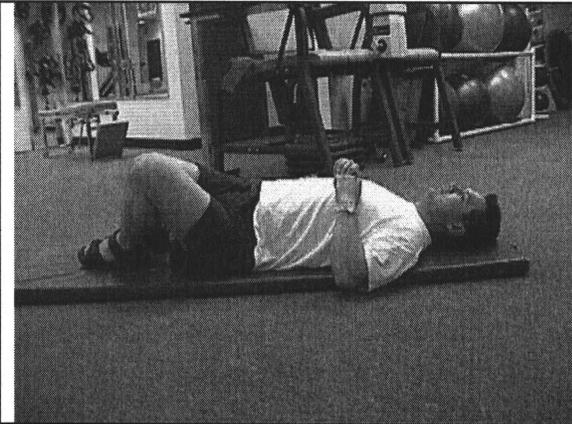
Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.



Begin with both knees bent up. Abdominal cocontract, and lower leg out to the ground at 45 degrees.

- _____ hold 5 seconds (at the end of the motion)
- _____ hold 8 seconds
- _____ hold 10 seconds
- _____ do 5 reps per arm
- _____ do 8 reps
- _____ do 10 reps

Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.



Abdominal cocontract and lower both legs to the left. Do not raise hips off the floor. Repeat to the other side.

_____hold 5 seconds (at the end of the motion)

_____hold 8 seconds

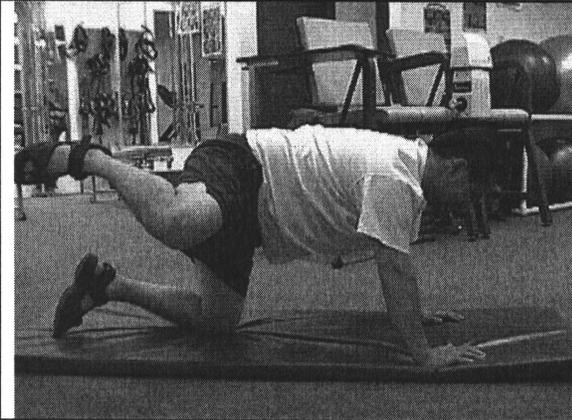
_____hold 10 seconds

_____do 5 reps per arm

_____do 8 reps

_____do 10 reps

Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.



Start on hands and knees. Abdominal cocontract. Lift right knee up to the side. Repeat to the left.

_____hold 5 seconds (at the end of the motion)

_____hold 8 seconds

_____hold 10 seconds

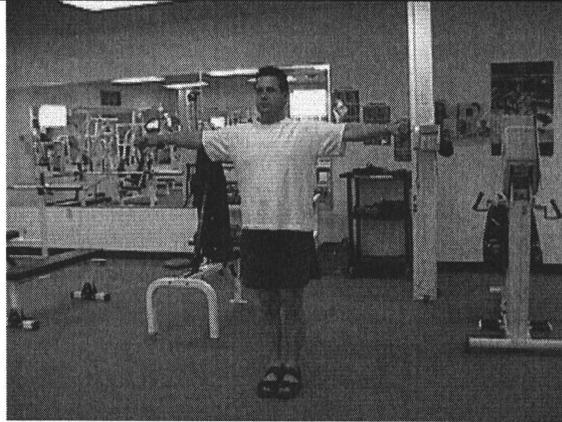
_____do 5 reps per arm

_____do 8 reps

_____do 10 reps

Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.

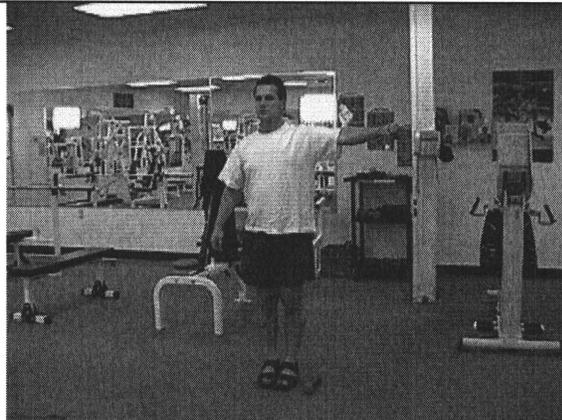
Trunk Stability – Frontal plane



Standing with _____ weight in each hand, abdominal cocontract – pull your belly button into your spine – and hold while raising both arms up to 90 degrees and lower.

- _____ hold 5 seconds
- _____ hold 8 seconds
- _____ hold 10 seconds
- _____ do 5 reps
- _____ do 8 reps
- _____ do 10 reps

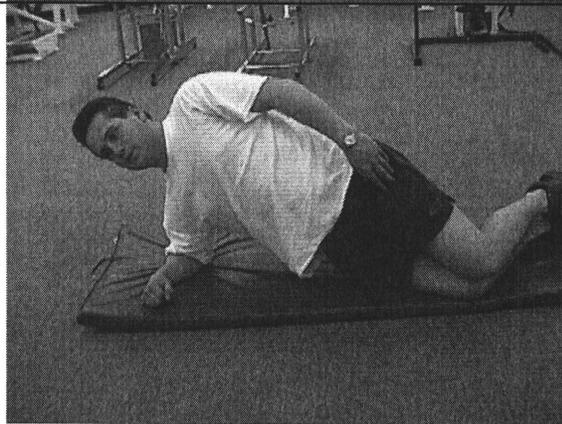
Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.



As above, but raise only one arm at a time up to 90 degrees and lower again.

- _____ hold 5 seconds
- _____ hold 8 seconds
- _____ hold 10 seconds
- _____ do 5 reps per arm
- _____ do 8 reps
- _____ do 10 reps

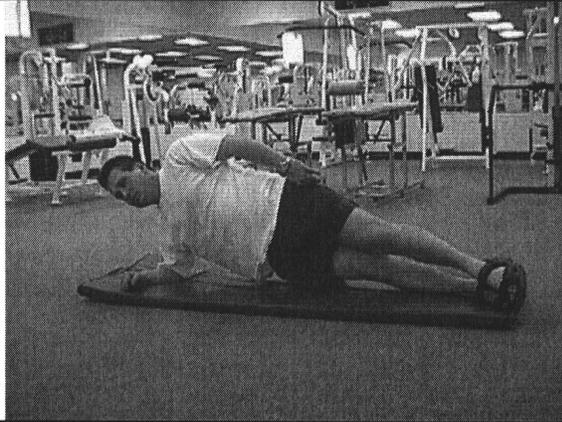
Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.



Sidebridge: Lying on your side propped up on your elbow, bring your pelvis forward and up until you are resting only on your elbow and knees.

- _____ hold 5 seconds
- _____ hold 8 seconds
- _____ hold 10 seconds
- _____ do 5 reps per side
- _____ do 8 reps
- _____ do 10 reps

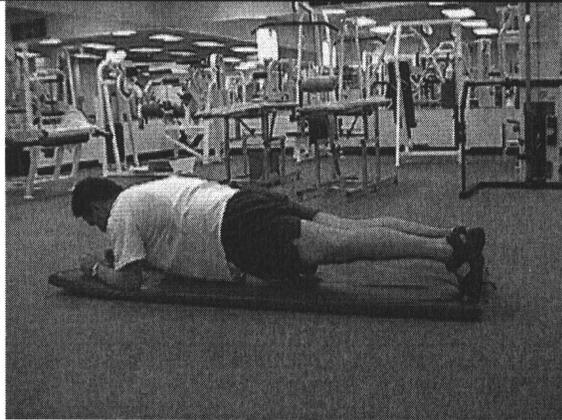
Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.



Repeat as above but this time coming up onto your elbow and feet.

- _____hold 5 seconds
- _____hold 8 seconds
- _____hold 10 seconds
- _____do 5 reps per side
- _____do 8 reps
- _____do 10 reps

Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.

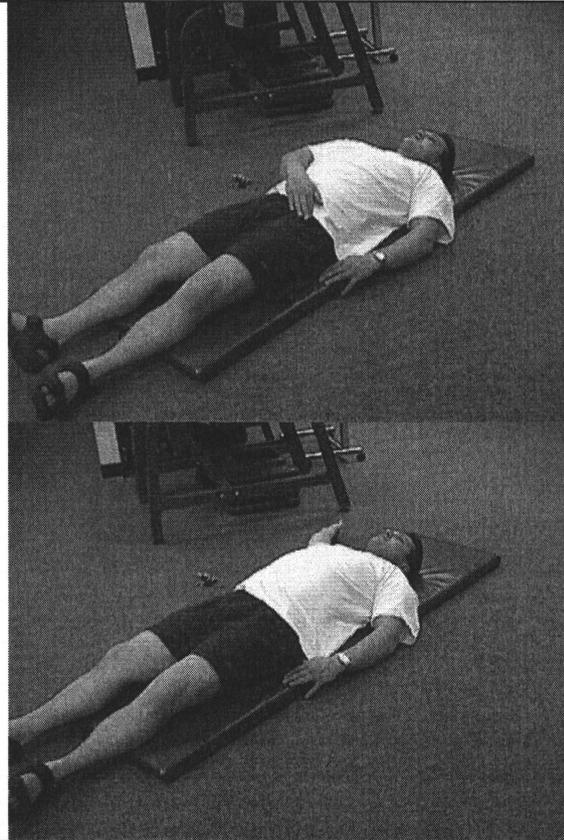


Sidebridge rollovers: Begin as above for sidebridge off feet, hold the required number of seconds, roll onto both elbows as shown here, hold the same number of counts, and roll onto your other elbow. Your spine must remain stiff with your body; your tummy must not sag at any time.

- _____hold 5 seconds
- _____hold 8 seconds
- _____hold 10 seconds
- _____do 5 reps
- _____do 8 reps
- _____do 10 reps

Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.

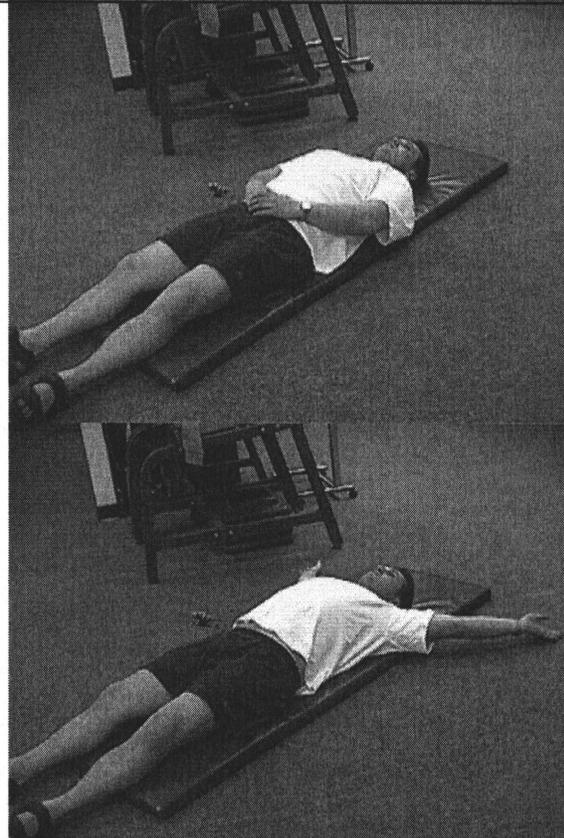
Trunk Stability – Combined Planes



Start with your right arm over on your left hip. Abdominal cocontract – pull your belly button into your spine. Lift your arm up and out to about 45 degrees from your body as shown, and lower to start again. Repeat with the other arm.

- _____ hold 5 seconds (at the end of the motion)
- _____ hold 8 seconds
- _____ hold 10 seconds
- _____ do 5 reps per arm
- _____ do 8 reps
- _____ do 10 reps

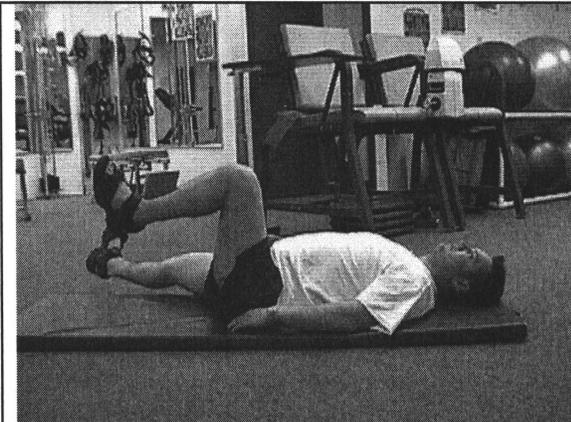
Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.



As above, but both hands at the same time.

- _____ hold 5 seconds at end of the motion
- _____ hold 8 seconds
- _____ hold 10 seconds
- _____ do 5 reps
- _____ do 8 reps
- _____ do 10 reps

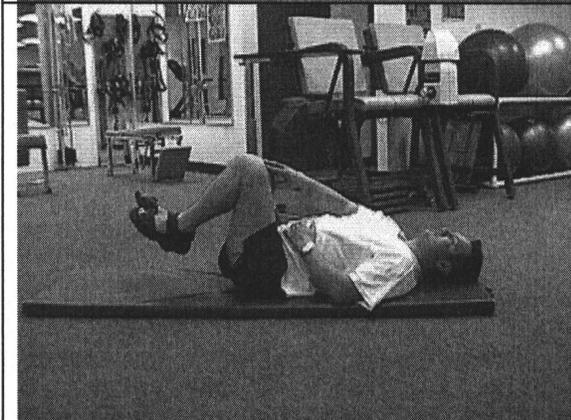
Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.



Begin with knees up at 90 degrees. Abdominal cocontract and lower 1 leg out at 45 degrees. Repeat other leg.

- _____ hold 5 seconds at end of the motion
- _____ hold 8 seconds
- _____ hold 10 seconds
- _____ do 5 reps
- _____ do 8 reps
- _____ do 10 reps

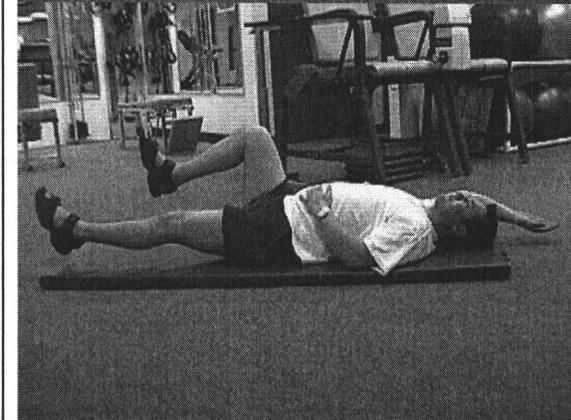
Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.



Begin with knees bent to 90 degrees and right hand on left knee. Abdominal cocontract, and lower right arm and left leg. Repeat other side.

- _____ hold 5 seconds at end of the motion
- _____ hold 8 seconds
- _____ hold 10 seconds
- _____ do 5 reps
- _____ do 8 reps
- _____ do 10 reps

Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.

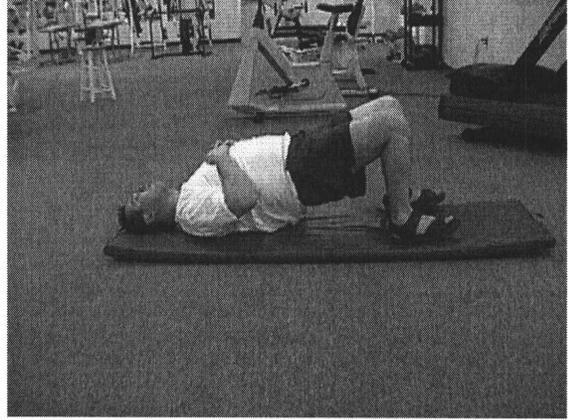
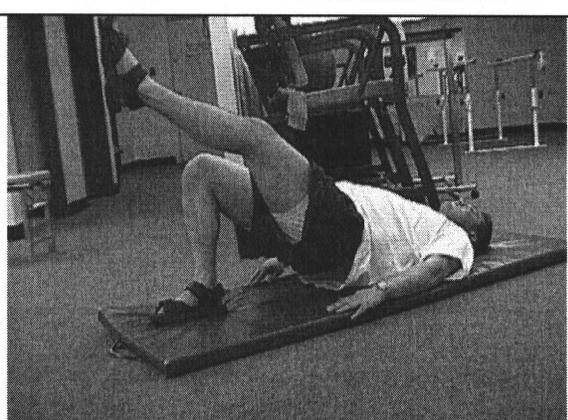
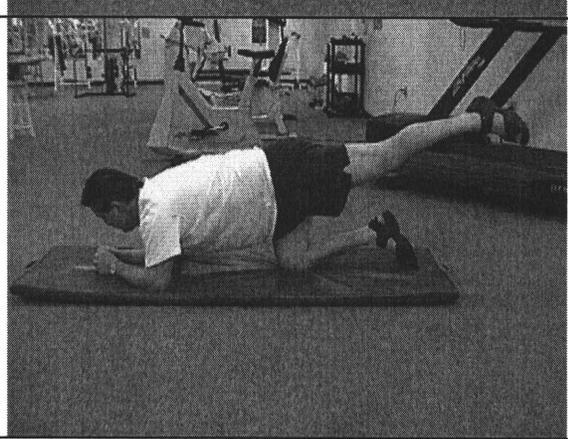


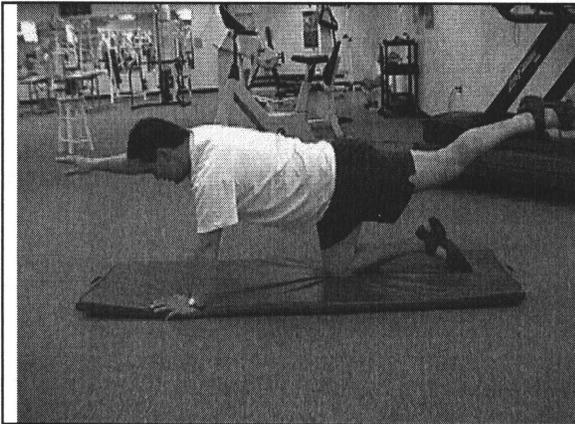
Begin with both knees at 90 degrees. Abdominal cocontract, and lower both legs out at 45 degrees.

- _____ hold 5 seconds at end of the motion
- _____ hold 8 seconds
- _____ hold 10 seconds
- _____ do 5 reps
- _____ do 8 reps
- _____ do 10 reps

Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.

Trunk Stability – Extension Plane

	<p>“Bridge”: Abdominal cocontract – pull your belly button in toward your spine and lift your buttocks until your tummy is level with your thighs.</p> <p> <input type="checkbox"/> hold 5 seconds <input type="checkbox"/> hold 8 seconds <input type="checkbox"/> hold 10 seconds <input type="checkbox"/> do 5 reps <input type="checkbox"/> do 8 reps <input type="checkbox"/> do 10 reps </p> <p>Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.</p>
	<p>Bridge as above. Once stable, straighten one leg as shown.</p> <p> <input type="checkbox"/> hold 5 seconds <input type="checkbox"/> hold 8 seconds <input type="checkbox"/> hold 10 seconds <input type="checkbox"/> do 5 reps per leg <input type="checkbox"/> do 8 reps <input type="checkbox"/> do 10 reps </p> <p>Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.</p>
	<p>Propped up on elbows, abdominal cocontract, and straighten one leg out behind you as shown,</p> <p> <input type="checkbox"/> hold 5 seconds <input type="checkbox"/> hold 8 seconds <input type="checkbox"/> hold 10 seconds <input type="checkbox"/> do 5 reps per leg <input type="checkbox"/> do 8 reps <input type="checkbox"/> do 10 reps </p> <p>Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.</p>



On hands and knees, abdominal cocontract, and lift one arm and the opposite leg straight up and out as shown.

- _____ hold 5 seconds
- _____ hold 8 seconds
- _____ hold 10 seconds
- _____ do 5 reps per side
- _____ do 8 reps
- _____ do 10 reps

Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.

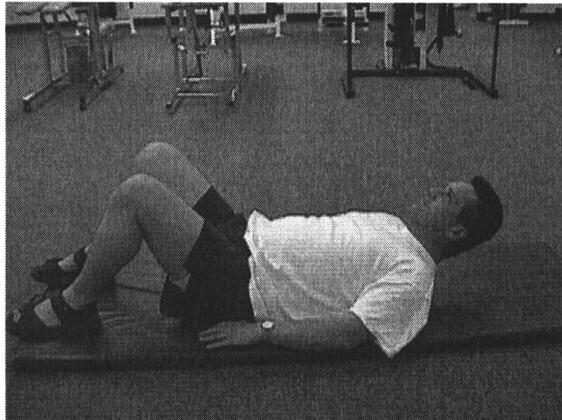


Standing with arms in front of you, abdominal cocontract, and lower your body as though you were sitting in a chair behind you.

- _____ hold 5 seconds
- _____ hold 8 seconds
- _____ hold 10 seconds
- _____ do 5 reps
- _____ do 8 reps
- _____ do 10 reps

Between reps, rest for as many seconds as you have just contracted. Rest for 3 minutes before the next exercise.

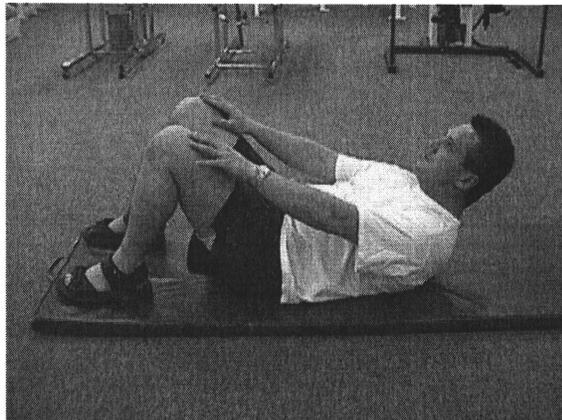
Movement Group Exercise Program
Trunk Movement – Sagittal Flexion Plane



Begin with your knees bent, feet on the floor, and hands by your sides. Lift your head off the floor.

- _____ 2 sets x 12 reps
- _____ 2 sets x 15 reps
- _____ 3 sets x 12 reps
- _____ 3 sets x 15 reps

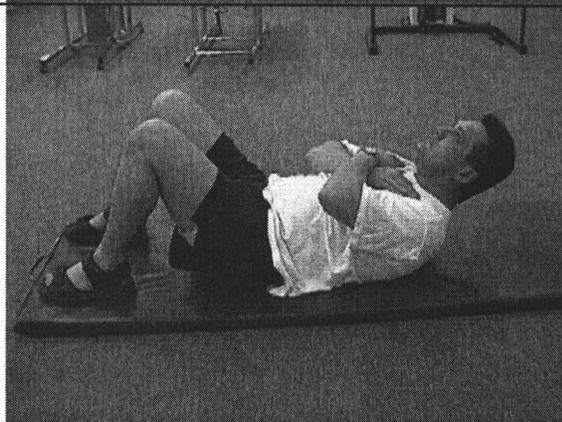
Rest 1 minute between sets. Rest 3 minutes between exercises.



Slide your hands up your thighs until you reach your knees.

- _____ 2 sets x 12 reps
- _____ 2 sets x 15 reps
- _____ 3 sets x 12 reps
- _____ 3 sets x 15 reps

Rest 1 minute between sets. Rest 3 minutes between exercises.

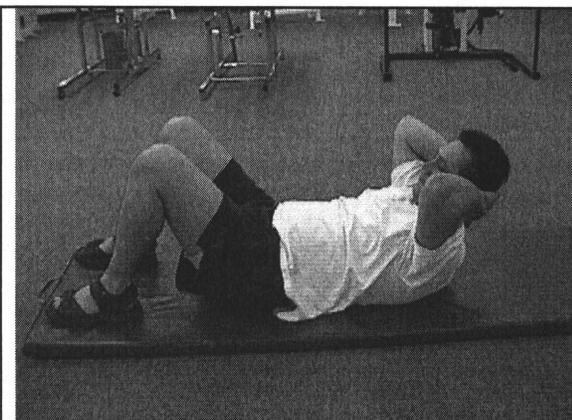


With hands crossed over your chest, crunch so that you lift your shoulders off the floor.

Do:

- _____ 2 sets x 12 reps
- _____ 2 sets x 15 reps
- _____ 3 sets x 12 reps
- _____ 3 sets x 15 reps

Rest 1 minute between sets. Rest 3 minutes between exercises.



Do a crunch with hands behind head.

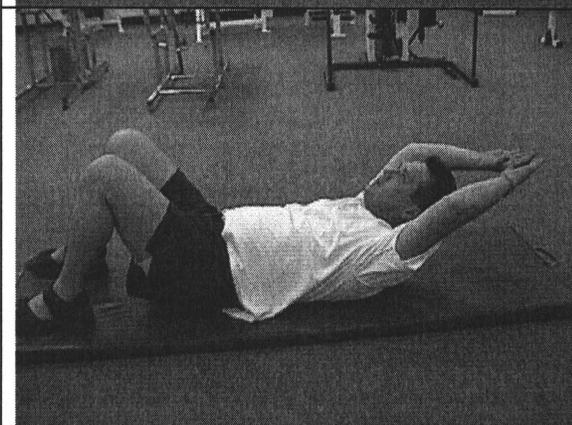
_____ 2 sets x 12 reps

_____ 2 sets x 15 reps

_____ 3 sets x 12 reps

_____ 3 sets x 15 reps

Rest 1 minute between sets. Rest 3 minutes between exercises.



Do a crunch with hands over head.

_____ 2 sets x 12 reps

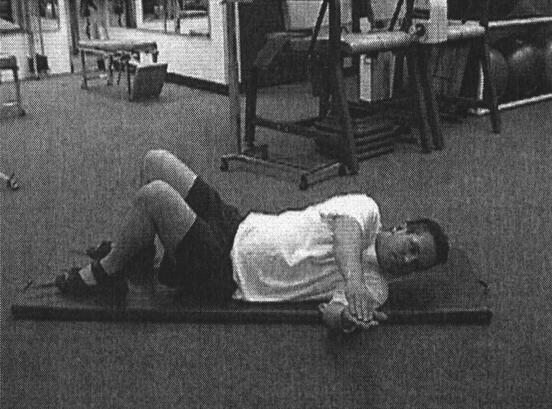
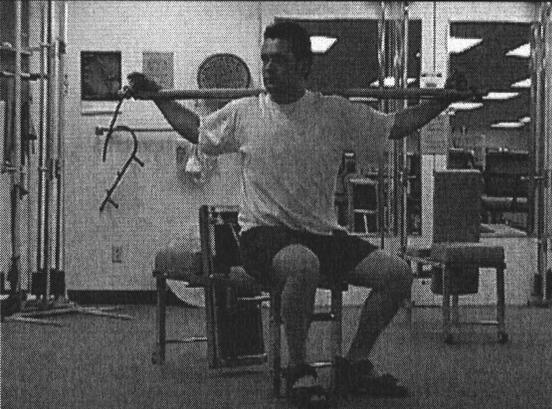
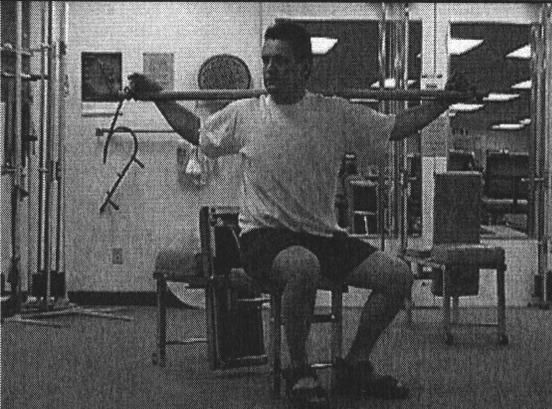
_____ 2 sets x 15 reps

_____ 3 sets x 12 reps

_____ 3 sets x 15 reps

Rest 1 minute between sets. Rest 3 minutes between exercises.

Trunk Movement – Transverse Plane

	<p>Lying on your back with knees bent up and hands out to your sides, twist upper body to reach left hand with right hand. Repeat to other side.</p> <p>_____ 2 sets x 12 reps _____ 2 sets x 15 reps _____ 3 sets x 12 reps _____ 3 sets x 15 reps</p> <p>Rest 1 minute between sets. Rest 3 minutes between exercises.</p>
	<p>Seated with broomstick over shoulders, twist to the left. Repeat to the right.</p> <p>_____ 2 sets x 12 reps _____ 2 sets x 15 reps _____ 3 sets x 12 reps _____ 3 sets x 15 reps</p> <p>Rest 1 minute between sets. Rest 3 minutes between exercises.</p>
	<p>Repeat as above with theraband attached to left end of broomstick and twist to right. Then switch theraband to right of broomstick and twist to left.</p> <p>_____ 2 sets x 12 reps _____ 2 sets x 15 reps _____ 3 sets x 12 reps _____ 3 sets x 15 reps</p> <p>Rest 1 minute between sets. Rest 3 minutes between exercises.</p>
	<p>Standing with broomstick over shoulders, twist to right. Repeat to left.</p> <p>_____ 2 sets x 12 reps _____ 2 sets x 15 reps _____ 3 sets x 12 reps _____ 3 sets x 15 reps</p> <p>Rest 1 minute between sets. Rest 3 minutes between exercises.</p>



Standing with broomstick over shoulders and theraband tied to left end, twist to right. Then switch theraband to right end and twist to left.

_____ 2 sets x 12 reps

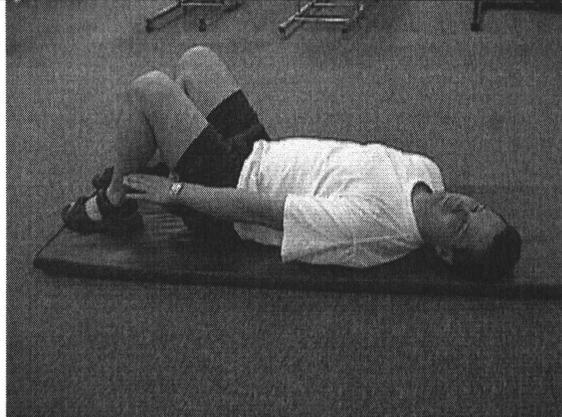
_____ 2 sets x 15 reps

_____ 3 sets x 12 reps

_____ 3 sets x 15 reps

Rest 1 minute between sets. Rest 3 minutes between exercises.

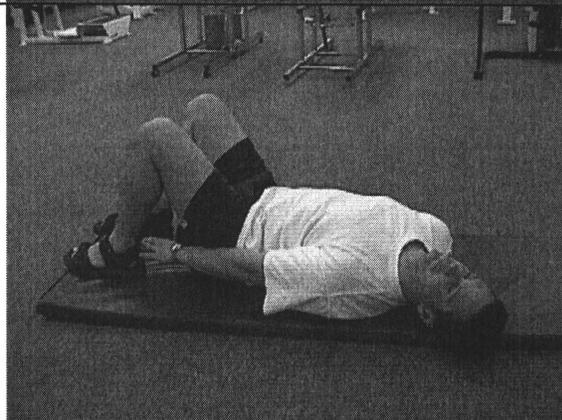
Trunk Movement – Frontal Plane



“Squirm”: Lying on your back with your knees bent up, reach with your left hand to your left foot.

- _____ 2 sets x 12 reps
- _____ 2 sets x 15 reps
- _____ 3 sets x 12 reps
- _____ 3 sets x 15 reps

Rest 1 minute between sets. Rest 3 minutes before the next exercise.



Squirm as above, but this time reach under your legs to your opposite foot.

- _____ 2 sets x 12 reps
- _____ 2 sets x 15 reps
- _____ 3 sets x 12 reps
- _____ 3 sets x 15 reps

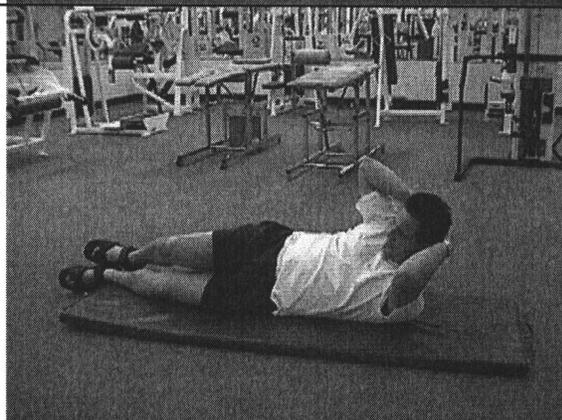
Rest 1 minute between sets. Rest 3 minutes before the next exercise.



Standing with broomstick, sidebend.

- _____ 2 sets x 12 reps
- _____ 2 sets x 15 reps
- _____ 3 sets x 12 reps
- _____ 3 sets x 15 reps

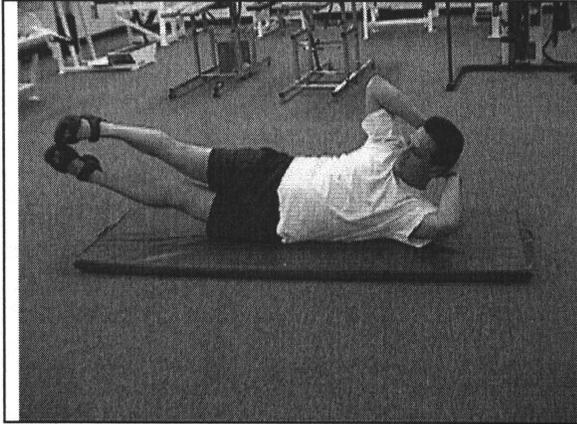
Rest 1 minute between sets. Rest 3 minutes before the next exercise.



Lying on your side with hands behind head, crunch up to the side. Go directly up to the side, so your right shoulder moves toward the right hip. Do not rotate.

- _____ 2 sets x 12 reps
- _____ 2 sets x 15 reps
- _____ 3 sets x 12 reps
- _____ 3 sets x 15 reps

Rest 1 minute between sets. Rest 3 minutes before the next exercise.



Side crunch as above, but lift legs at same time as crunching from above.

_____ 2 sets x 12 reps

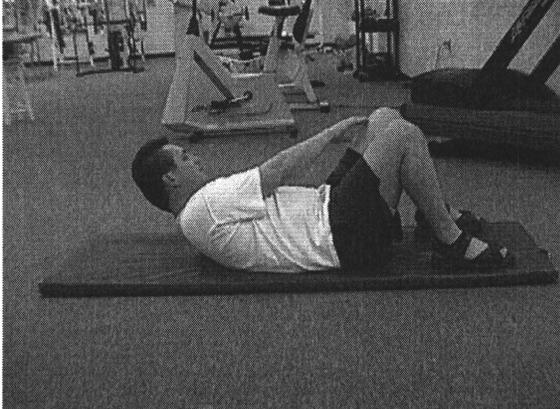
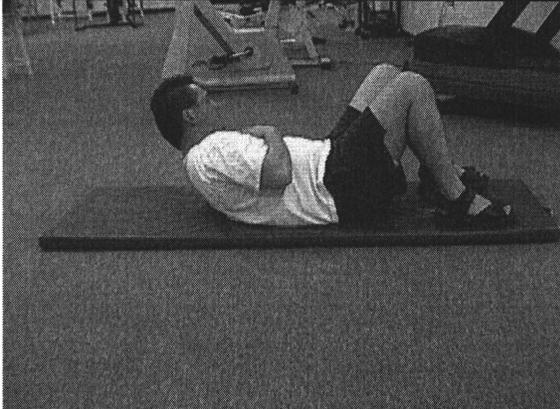
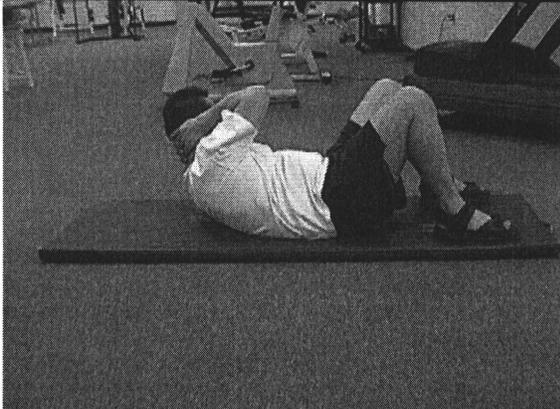
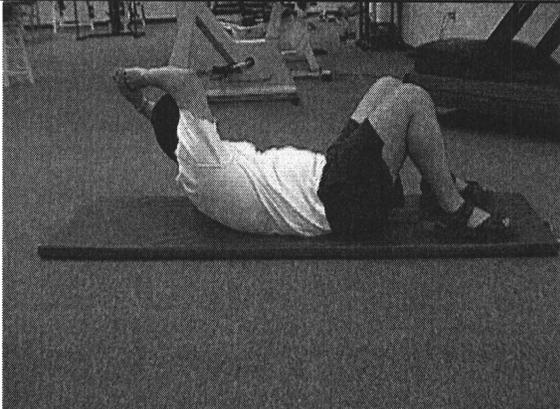
_____ 2 sets x 15 reps

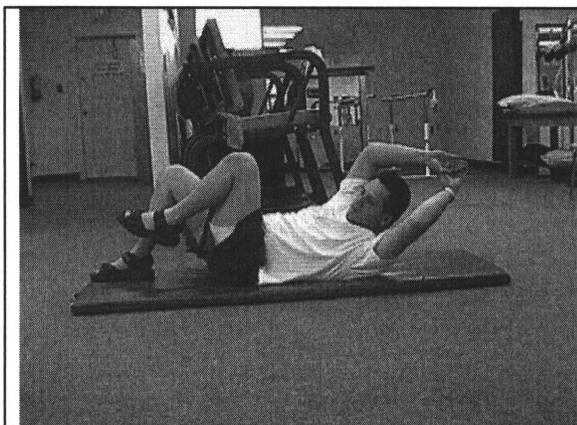
_____ 3 sets x 12 reps

_____ 3 sets x 15 reps

Rest 1 minute between sets. Rest 3 minutes before the next exercise.

Trunk Movement – Combined Planes

	<p>Crunch to reach your left knee with your right hand. Now repeat with the left.</p> <p>_____ 2 sets x 12 reps _____ 2 sets x 15 reps _____ 3 sets x 12 reps _____ 3 sets x 15 reps</p> <p>Rest 1 minute between sets. Rest 3 minutes before the next exercise.</p>
	<p>Hands crossed over chest, crunch toward your left knee. Then repeat to the right.</p> <p>_____ 2 sets x 12 reps _____ 2 sets x 15 reps _____ 3 sets x 12 reps _____ 3 sets x 15 reps</p> <p>Rest 1 minute between sets. Rest 3 minutes before the next exercise.</p>
	<p>Hands behind your head, crunch as above.</p> <p>_____ 2 sets x 12 reps _____ 2 sets x 15 reps _____ 3 sets x 12 reps _____ 3 sets x 15 reps</p> <p>Rest 1 minute between sets. Rest 3 minutes before the next exercise.</p>
	<p>Hands overhead, crunch as above.</p> <p>_____ 2 sets x 12 reps _____ 2 sets x 15 reps _____ 3 sets x 12 reps _____ 3 sets x 15 reps</p> <p>Rest 1 minute between sets. Rest 3 minutes before the next exercise.</p>



Hands overhead, crunch to left knee, while lifting left knee up to 90 degrees.

_____ 2 sets x 12 reps

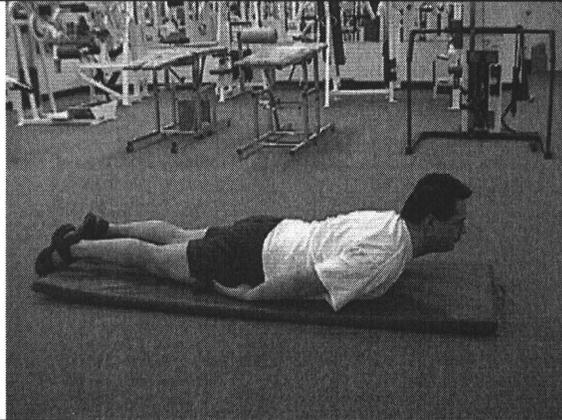
_____ 2 sets x 15 reps

_____ 3 sets x 12 reps

_____ 3 sets x 15 reps

Rest 1 minute between sets. Rest 3 minutes before the next exercise.

Trunk Movement – Extension Plane



With your hands at your sides, lift your chest off the floor.

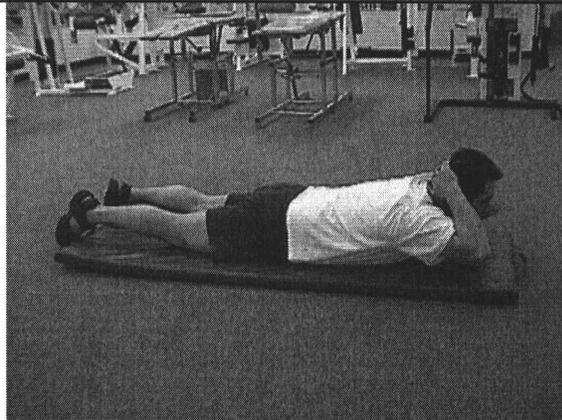
_____ 2 sets x 12 reps

_____ 2 sets x 15 reps

_____ 3 sets x 12 reps

_____ 3 sets x 15 reps

Rest 1 minute between sets. Rest 3 minutes between exercises.



With your hands behind your head, lift your chest off the floor.

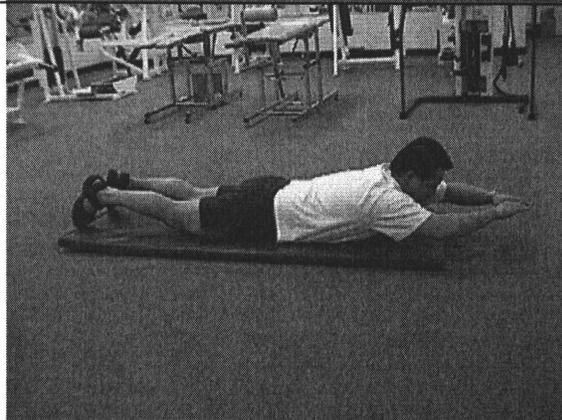
_____ 2 sets x 12 reps

_____ 2 sets x 15 reps

_____ 3 sets x 12 reps

_____ 3 sets x 15 reps

Rest 1 minute between sets. Rest 3 minutes between exercises.



With your arms above your head, lift your chest off the floor.

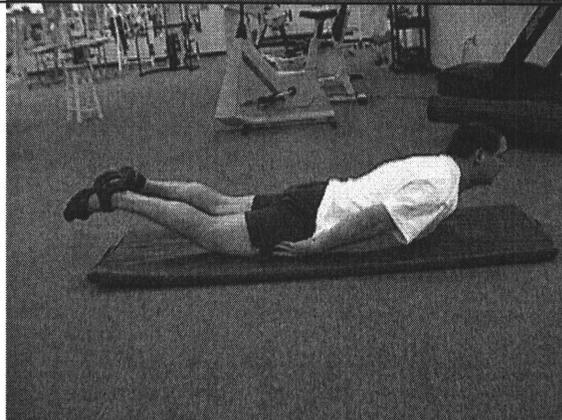
_____ 2 sets x 12 reps

_____ 2 sets x 15 reps

_____ 3 sets x 12 reps

_____ 3 sets x 15 reps

Rest 1 minute between sets. Rest 3 minutes between exercises.



With your arms by your side, lift your chest and legs off the floor.

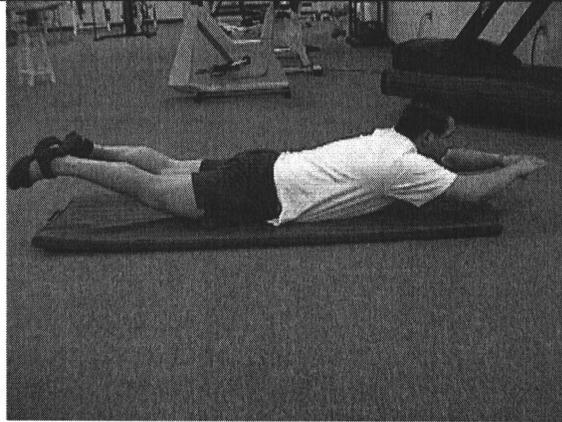
_____ 2 sets x 12 reps

_____ 2 sets x 15 reps

_____ 3 sets x 12 reps

_____ 3 sets x 15 reps

Rest 1 minute between sets. Rest 3 minutes between exercises.



“Superman”: with your arms overhead, lift your chest and legs off the floor.

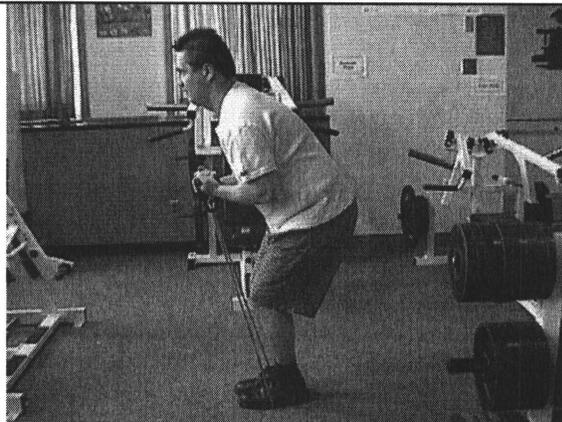
_____ 2 sets x 12 reps

_____ 2 sets x 15 reps

_____ 3 sets x 12 reps

_____ 3 sets x 15 reps

Rest 1 minute between sets. Rest 3 minutes between exercises.



Standing back extension” with one end of the tubing in each hand and the middle of the tubing under your feet, begin with knee slightly flexed, back in a neutral arch and leaning slightly forward at the hips. Then while holding the tubing ends in front of your chest, straighten up against the resistance of the tubing.

_____ 2 sets x 12 reps

_____ 2 sets x 15 reps

_____ 3 sets x 12 reps

_____ 3 sets x 15 reps

Rest 1 minute between sets. Rest 3 minutes between exercises.



Appendix E
Reliability Pilots Data Sheets

Reliability Pilot May 2002 – Stability Endurance and Abdominal Ultrasound

A. Personal Data

Name:

ID:

B. Endurance Pilot: first test date:

a. Maximal Leg Lowering Angle (degrees):

1.

2.

3.

best score:

b. Relative Leg Gravitational Torque Calculation: $\frac{\cos ?}{\cos 0} * 100 \% =$

c. 60 % of above torque = _____ (degrees)

d. Endurance (time held at 60 %, maximum time 120 seconds, tested one time only) =

C. Ultrasound Pilot first test date

(3 measures and average the 2 closest; do a 4th if true median of 3)

a. Rectus Abdominis: _____ average of 2 closest _____

b. External Oblique: _____ average of 2 closest _____

c. Internal Oblique: _____ average of 2 closest _____

d. Transverse Abdominis: _____ average of 2 closest _____

Combined Thickness:

average rectus + average external + average internal + average transverse = _____

Reliability Pilot May 2002 – Stability Endurance and Abdominal Ultrasound

A. Personal Data

Name:

ID:

B. Endurance Pilot second test date:

- a. 60 % of Relative Leg Gravitational Torque Calculation from first test
- b. Endurance (time held at 60 %, maximum time 120 seconds, tested one time only) =

C. Ultrasound Pilot second test date:

(3 measures and average the 2 closest; do a 4th if true median of 3)

- a. Rectus Abdominis: _____ average of 2 closest _____
- b. External Oblique: _____ average of 2 closest _____
- c. Internal Oblique: _____ average of 2 closest _____
- d. Transverse Abdominis: _____ average of 2 closest _____

Combined Thickness:

average rectus + average external + average internal + average transverse = _____

Appendix F
Ethics Approval



**UNIVERSITY OF SASKATCHEWAN ADVISORY COMMITTEE ON
ETHICS IN HUMAN EXPERIMENTATION**

(BIOMEDICAL SCIENCES)

<http://www.usask.ca/research/ethics.shtml>

ORS USE ONLY

File Number:

Date

Received:

RESEARCHER'S SUMMARY

PROJECT TITLE:

A Comparison of the Effect of Trunk Stability and Trunk Movement Strengthening on Vertical Take-off Velocity

SUBMITTED BY: Stacey Donnelle Lovo **DEPARTMENT:** College of Kinesiology

CO-INVESTIGATOR(S): Bruce Craven, Dr. Eric Sprigings **DEPARTMENT:**
College of
Kinesiology

RESEARCH WILL BE CONDUCTED AT: College of Kinesiology, University of Saskatchewan

1. **Hypothesis** (State briefly the nature and purpose of the research proposal, and the proposition the research is seeking to uphold. What potentially useful knowledge or clarification about therapeutic options will be advanced to justify the participation of human subjects in this research project?):

There is no published research examining the influence of trunk stability training on a functional outcome. This research will determine the influence of trunk stability and trunk movement training on vertical take-off velocity. Trunk stability training involves the performance of trunk exercise while a neutral spine position is maintained. Trunk movement training refers to trunk exercise in the presence of spinal movement.

Vertical jump is a common sporting skill. Defining a method of improving vertical jump height would be useful in many different sports.

Questions to be examined include:

- a. Does trunk stability training result in greater vertical take-off velocity than trunk movement strengthening?
- b. Does trunk stability training result in greater hypertrophy of abdominal obliques and transversus abdominis muscles than trunk movement strengthening?
- c. Does trunk movement strengthening result in greater hypertrophy of rectus abdominis than trunk stability training?

- d. Does trunk stability training result in greater recruitment of internal oblique muscles than trunk movement strengthening?
- e. Does trunk movement strengthening result in greater recruitment of rectus abdominis than trunk stability training?

The hypothesis of this study is that trunk stability training will result in greater hypertrophy of oblique abdominal and transversus abdominis muscles, greater recruitment of internal oblique muscles and greater vertical take-off velocity than trunk movement strengthening.

2. Academic Validity (Provide evidence that the scientific reasoning and design of the project are sufficiently sound to meet the objectives of this project. Provide your own comments and those resulting from peer review. Indicate if any committee or other body has assessed the project's scientific validity):

Achieving maximal vertical jump height is important in many athletic events. The ability to achieve maximal jump height depends on leg power and also the ability to maintain proper trunk stability. We have previously shown that trunk stability correlates with vertical jump ability. We therefore hypothesize that a training program geared towards improving trunk stability will improve vertical jump height. The advisory committee to Stacey Lovo (Bruce Craven, Dr. Eric Sprigings, Dr. Phil Chilibeck and Dr. Kevin Spink) has agreed to this proposed research study.

3. Funding (indicate the source of funds supporting the research. If externally funded, state whether the grant or contract is still in application, or has already been awarded):

Not funded

4. Disclosure of Potential Conflicts of Interest (indicate any motivation or incentives for conducting this study that arise external to the objectives of the study, e.g., will the investigator or institution be paid to conduct this research project? Note: The consent form should also include an introductory disclosure of potential conflict of interest statement indicating that this is a medical research study for which the study doctor is being paid to conduct):

None

5. Subjects (target population e.g., age, gender, medical condition, target enrollment at this site, proposed strategies that will be used to recruit to this study):

Sixty healthy male and female participants greater than age 18 will be recruited by the use of posters around the University of Saskatchewan, SIAST Kelsey Campus, City of Saskatoon fitness facilities and rehabilitation facilities. Exclusion criteria will include the presence of back, neck or leg pain, cardiovascular disease, body mass index greater than 30 kg/m² and prior abdominal training of greater than three days per week

6. Procedures (clearly identify treatment allocation design, and describe the medical and other procedures to be followed in obtaining research data):

Subjects will be randomized to trunk movement training, trunk stability training, or non-training control groups. All exercises utilized in this study will be exercises that are

commonly used in rehabilitation settings. No uncommon exercises will be utilized. Training will occur over a twelve week period. Exercise will take approximately 20-30 minutes, 3 times / week. Two of these sessions will be performed at the participants' homes, while the third will be performed at the College of Kinesiology in the presence of the researcher. Control participants will perform placebo exercises in the form of stretching and will be contacted by telephone every second week to monitor their physical activity patterns.

At baseline, 3 weeks, and 12 weeks, the following measures will be performed: 1) ultrasound to measure thickness of specific abdominal muscles; 2) surface electromyography to measure muscle recruitment; 3) vertical take-off velocity determined by jumping from a force platform; 4) strength and endurance of the abdominal muscles by straight leg lowering maneuvers.

For clarity of measurement with ultrasound and EMG, the participants will be required to shave their abdomen if needed over measurement areas. Skin will be cleaned with alcohol swabs prior to measurements. Leg lowering measures will be carefully monitored to ensure lumbar safety. If a participant fails to maintain the correct technique, the test will be stopped to ensure safety.

7. Time Period (indicate the dates when the research project is expected to begin and to be completed. A final status report must be filed with the Office of Research Services once data collection from the last subject is complete. ORS should be notified once the study site is closed.):

The anticipated start date for the research phase of this study is June 3, 2002 with a completion date of September 13, 2002.

8. Consent Form (include a copy of the study information / consent form that will be used, or give reasons if one is not being used):

Please refer to the attached consent form.

9. By signing below, the Principal Investigator is assuring the Biomedical Ethics Committee that the Department Head (or corresponding senior administrator) has received a copy of this *Researchers' Summary Form*. (NOTE: This policy will function in lieu of the previous policy that required countersigning of this *Researchers' Summary Form* by the Department Head).

Principal Investigator

Phone

Fax

e-mail

10. Contact Person and Mailing Address for Correspondence: Stacey Lovo, College of Kinesiology, U of S, Saskatoon, Sk., S7N 5C2, Phone: _____, e-mail _____@mail.usask.ca



Certificate of Approval

PRINCIPAL INVESTIGATOR E. J. Sprigings	DEPARTMENT Kinesiology	BMC # 02-459
--------------------------------------------------	----------------------------------	------------------------

INSTITUTION (S) WHERE RESEARCH WILL BE CARRIED OUT

University of Saskatchewan
College of Kinesiology
105 Gymnasium Place
Saskatoon SK S7N 5C2

SPONSORING AGENCIES

UNFUNDED

TITLE:

A Comparison of the Effect of Trunk Stability and Trunk Movement Strengthening on Vertical Take-Off Velocity

ORIGINAL APPROVAL DATE 03-May-2002	CURRENT EXPIRY DATE 01-May-2003	APPROVAL OF Protocol and Consent Form as submitted Advertisement as submitted
----------------------------------------------	-------------------------------------------	--------------------------------------------------------------------------------------------

CERTIFICATION

The University of Saskatchewan Biomedical Research Ethics Board (Bio-REB) has reviewed the above-named research project. The proposal was found to be acceptable on ethical grounds. The principal investigator has the responsibility for any other administrative or regulatory approvals that may pertain to this research project, and for ensuring that the authorized research is carried out according to governing law. This Certificate of Approval is valid for the above time period provided there is no change in experimental procedures

ONGOING REVIEW REQUIREMENTS

In order to receive annual renewal, a status report must be submitted to the Chair for Committee consideration within one month of the current expiry date each year the study remains open, and upon study completion. Please refer to the following website for further instructions: <http://www.usask.ca/research/ethics.shtml>. In respect of the identified clinical trial, the University of Saskatchewan Research Ethics Board complies with the membership requirements for Research Ethics Boards defined in Division 5 of the Food and Drug Regulations, and carries out its functions in a manner consistent with Good Clinical Practices. This approval and the views of this REB have been documented in writing.

APPROVED.

D.W. Quest, Chair
University of Saskatchewan
Biomedical Research Ethics Board

Please send all correspondence to:

Office of Research Services
University of Saskatchewan
Room 210 Kirk Hall, 117 Science Place
Saskatoon, SK S7N 5C8

Appendix G
Recruitment

ABDOMINAL RESEARCH STUDY

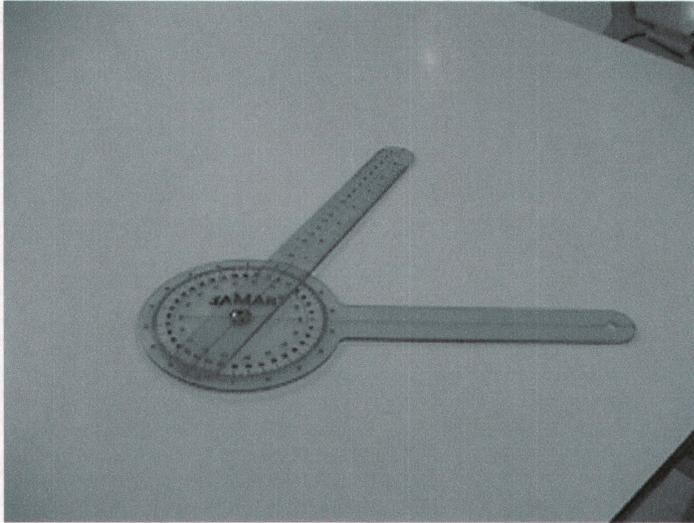
Eager participants are needed for a research study on the training of abdominal muscles at the College of Kinesiology, University of Saskatchewan. This study will examine two different methods of training abdominals and the effect they have on jumping. If you are 18 or older, and do not have back, neck, leg pain or heart disease, you are eligible to participate. If you currently train your abdominals more than 3 times/week, you are ineligible to participate.

This is ground breaking research! No published studies have examined the influence of different methods of abdominal training on a function (like jumping).

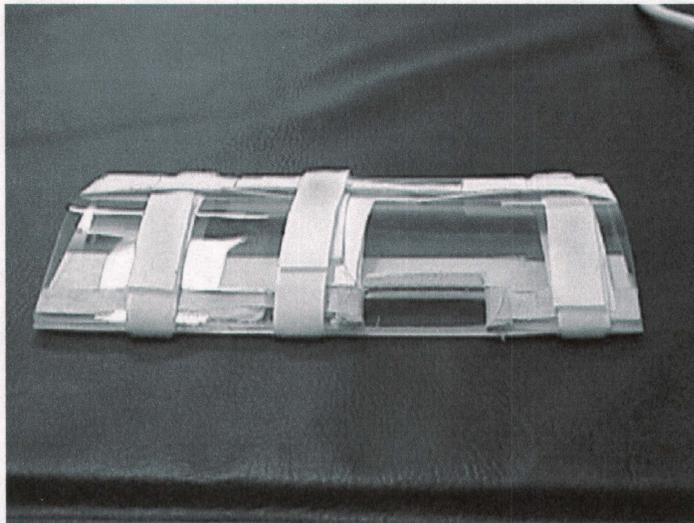
The study begins June 10, 2002, and ends September 20, 2002. You may be assigned to one of two treatment groups or a non-training control. The training will require approximately 30 minutes, 3 times/week. In addition, testing on stomach muscles and jumping will be done at the College of Kinesiology before training, at 3 weeks, and after the training is done. Testing will take approximately 45 minutes each time. Benefit from training is not guaranteed.

If you want to participate in ground breaking research, call Stacey Lovo at _____ or e-mail _____@mail.usask.ca

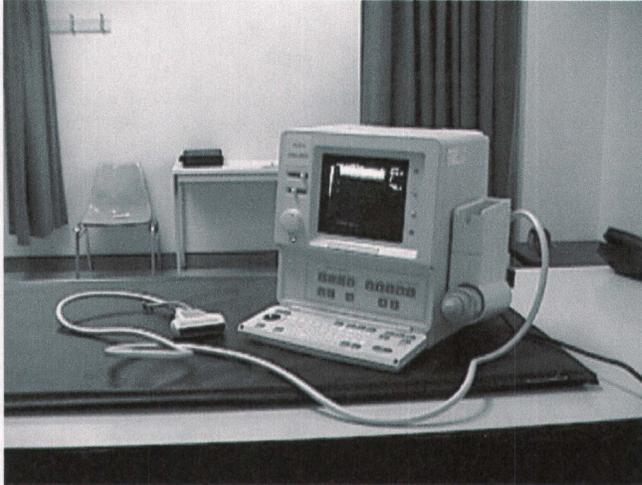
Appendix H
Testing Equipment and Procedures



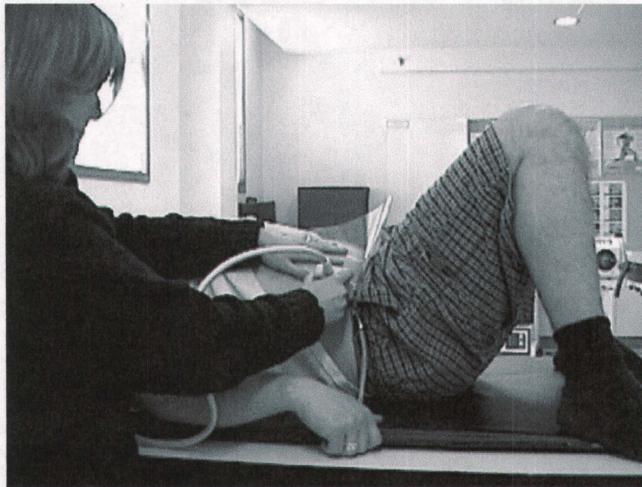
A Jamar universal goniometer for measuring leg angle in the double straight leg lowering procedures



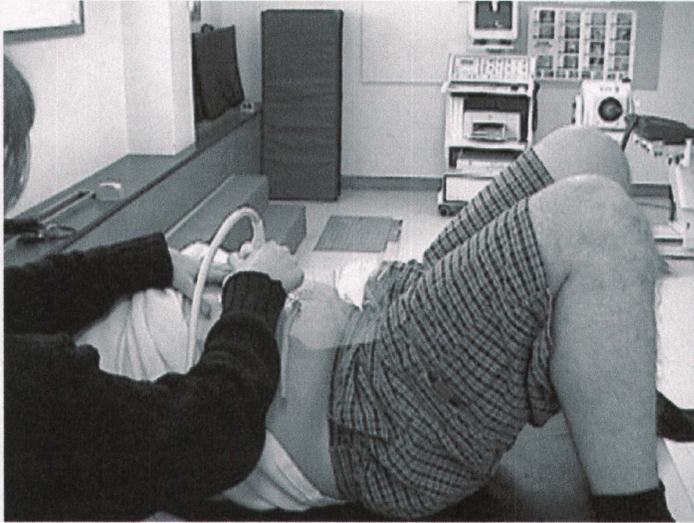
Plexiglass support to hold and pre-set the sphygmomanometer cuff (Butcher, 2001)



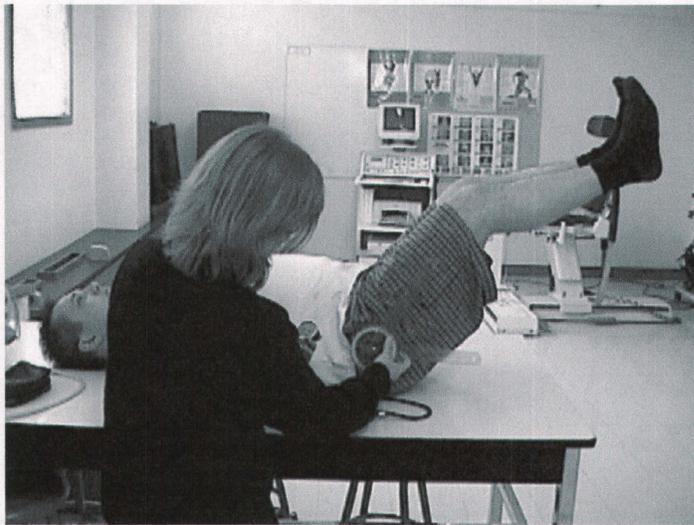
B-mode ultrasound (Aloka SSD-500, Tokyo, Japan) for abdominal muscle thickness measures



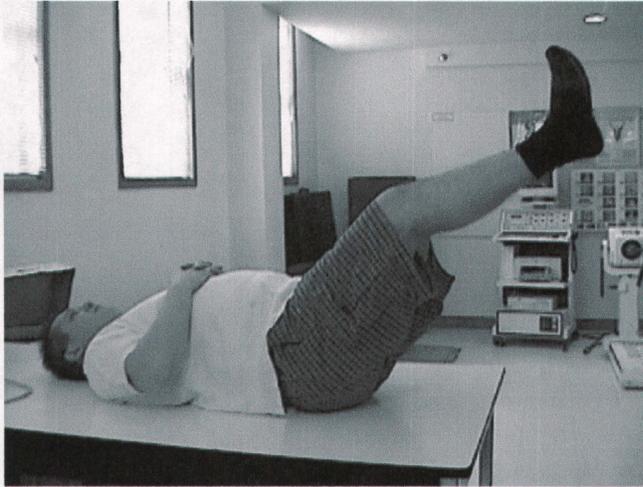
The investigator performing the abdominal ultrasound muscle thickness procedure for internal oblique, external oblique and transverse abdominis



The investigator performing the abdominal ultrasound muscle thickness procedure for rectus abdominis



The investigator measuring the double straight leg lowering angle and sphygmomanometer cuff pressure



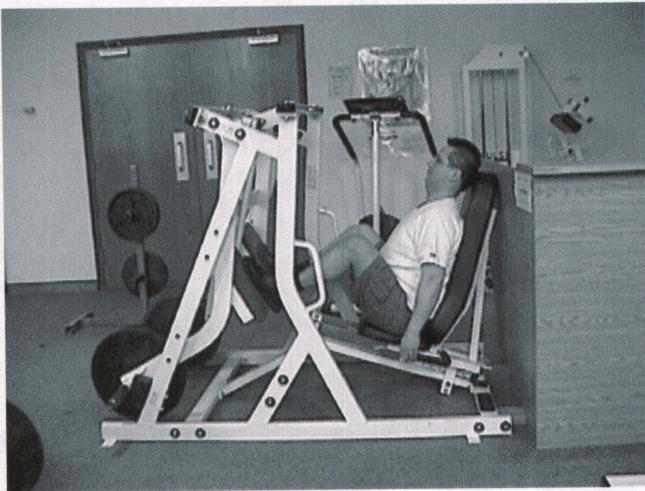
Participant during the double straight leg lowering maneuver



Participant standing still prior to vertical jump



Participant initiating a vertical jump



Participant performing the leg strength test

Appendix I

Syntax Modification for Statistical Analysis

```

GLM
  jump0 jump3 jump12 BY group WITH weight 1.press0
  /WSFACTOR = time 3 Polynomial
  /METHOD = SSTYPE(3)
  /PLOT = PROFILE( time*group )
  /EMMEANS = TABLES(group) WITH(weight=MEAN 1.press0=MEAN) COMPARE
ADJ(LSD)
  /EMMEANS = TABLES(time) WITH(weight=MEAN 1.press0=MEAN) COMPARE
ADJ(LSD)
  /EMMEANS = TABLES(group*time) WITH(weight=MEAN 1.press0=MEAN)
/EMMEANS = TABLES(group*time) compare (group)
/EMMEANS = TABLES(group*time) compare (time)
  /PRINT = DESCRIPTIVE ETASQ HOMOGENEITY
  /CRITERIA = ALPHA(.05)
  /WSDESIGN = time
  /DESIGN = weight 1.press0 group .

```

The above lines in bold have been added to this syntax to achieve the desired comparisons in the output.