2010

Comparing the effects of inspiratory muscle training and core training on core muscle function

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COMPARING THE EFFECTS OF INSPIRATORY MUSCLE TRAINING AND CORE TRAINING ON CORE MUSCLE FUNCTION

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Accepted in Partial Completion
Of the Requirements for the Degree
Master of Science

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MASTER'S THESIS

COMPARING THE EFFECTS OF INSPIRATORY MUSCLE TRAINING AND CORE TRAINING ON CORE MUSCLE FUNCTION

A Thesis
Presented to
The Faculty of
Western Washington University

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July 2010

Abstract

This study was designed to test the effects of inspiratory muscle training on core function compared to a typical core training program. One group performed inspiratory muscle training for six weeks while another performed a core training program of the same duration. A third group served as controls. Core function was assessed pre and post training using a side bridge, prone extension and Stabilizer test of transversus abdominis contraction. Maximal inspiratory pressure was also assessed before and after the six week training period. A two-way repeated measures analysis of variance (ANOVA) was used to determine the significance of inspiratory muscle training and core training on the tests of core function. The results showed a significant increase in maximal inspiratory pressure in the inspiratory muscle training group from 1.06(sd=0.37) to 1.72 cm H_20 (sd=0.42), p=0.000. The core training group significantly improved their time of the prone extension test from 114.0 (sd=53.0) to 154.0 seconds (sd=77.6), p=0.014. The inspiratory muscle training group had a significantly improved performance over the core training group on the Stabilizer test, with the core training group actually showing a poorer performance following training. The inspiratory muscle training group improved on the Stabilizer test from a mean score of -6.9 mm Hg (sd=12.6) to -10.0 mm Hg (sd=11.0), p=0.038. Six weeks of core training and inspiratory muscle training can both improve core function and target different muscles.

Acknowledgements

I am grateful for the many people in my life who have helped me through this process. My fellow graduate students have assisted in the project, from helping recruit subjects to entertaining me during countless hours spent in the physiology lab. Anuja Choudhari deserves a special thank you for her assistance with the daily training sessions. I would also like to thank Drs. Kathleen Knutzen and Brandi Row for their support and contribution to this thesis. Thank you Dr. Lorraine Brilla for the time, patience, and straight talk I needed in order to be successful. I would like to acknowledge my mentors Jill Wolfson and Ron Arnold have helped in bridging the gap between my academic lessons and the workplace, giving my hard work a purpose. Both have inspired me to complete my thesis and my graduate studies and pursue a career I am passionate about. My best friend and future husband, Ryan Kauffman, has provided the comic relief I have so desperately needed over the last two years. It would not have been possible without him.

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Chapter I:

The Problem and Its Scope

Introduction

Core training has grown in popularity recently. Strength training for the abdominals and lower back is used for many purposes, including improving athletic performance and relieving low back pain. Including core stability as part of an overall conditioning program for athletes has been shown to improve athletic performance (Myer, Ford, Palumbo, & Hewett, 2005). Core training alone, however, has not been shown to have an impact on athletic performance (Akuthota, Ferreiro, Moore, & Fredericson, 2008). Core function also influences low back pain (Hides et al., 2008) and it has been shown that recruitment of core muscles is altered in people with low back pain (Hodges, Moseley, Gabrielsson, & Gandevia, 2003). Transversus abdominis (TrA) function is a key component of low back pain treatment and prevention (Hides et al., 2008; Hodges et al., 2003) and those without a history of low back pain activate the TrA before movement of the trunk or extremities, while those with low back pain activate the TrA after the movement is initiated (Hodges et al., 2003). Training these recruitment patterns, especially recruitment of the TrA, might help prevent low back pain (Hodges et al., 2003).

Yoga and Pilates are popular forms of exercise which incorporate breathing with movements. Strength and stability gains observed in these programs may be related to the focus on breathing (Herrington & Davies, 2005). A Pilates program can improve one's ability to contract the transversus abdominis, an important skill for core strength and stability (Herrington & Davies, 2005). The deep breathing used during yoga can increase core muscle activation and improve cardiorespiratory function (Upadhyay Dhungel, Malhotra, Sarkar, & Prajapati, 2008).

Deep breathing exercises have been shown to require more abdominal muscle activity than abdominal crunches (Petrofsky, Cuneo, Dial, & Morris, 2005) and it is suggested that breathing exercises can be incorporated into a core training program in order to achieve maximum benefits. Inspiratory muscle training is one way to train the muscles used during respiration (Gething, Williams, & Davies, 2003). Research has consistently shown that inspiratory muscle training improves respiratory muscle strength, but how this influences core stability is unknown (Downey et al., 2007; Johnson, Sharpe, & Browne, 2007; Nicks, Morgan, Fuller, & Caputo, 2009; Sanchez Riera et al., 2001).

Purpose of the Study

This study investigates the influence of inspiratory muscle training on core function compared to a typical core training program. It will determine if increased strength of the respiratory muscles shows similar improvements on tests of core strength and stability as a core training program.

Hypothesis

The null hypothesis states there will be no significant difference in core function tests between subjects who perform inspiratory muscle training and those who perform core exercises. Core function will be tested using a side bridge endurance test, back extension endurance test, and a test of transversus abdominis function using a pressure biofeedback unit. There will be no difference in performance on these tests between the two training groups and a control group.

Significance of the Study

This study provides information on how breathing, specifically inspiratory muscle training (IMT), can affect the function of core muscles. If similar results are found between IMT and core training, breathing exercise may be used as alternative to traditional training of core muscles.

Limitations of the Study

1. Subjects were not randomly assigned to IMT, core training, or control groups. Core training subjects were recruited from a fitness class in which they had already elected to participate.
2. IMT breathing patterns and exact loads may vary by subject. The researchers provided instructions on proper use of the IMT device, but respiration rate could not be controlled.
3. There may be a practice effect on the test of MIP. Subjects in the IMT group will have performed the MIP test maneuver more often than the other two groups which may give them an advantage over the other subjects.
4. The core training group took AbLab classes from different instructors and may have had varying levels of training intensity and exercise progression.
5. There may be differences in activity levels between groups. All subjects were instructed to maintain their current level of activity throughout the study. A kilocalorie expenditure analysis was conducted during the pre and post-testing to verify.

Definition of Terms

Back Extension Endurance Test: a maximal test that measures the time a subject can maintain a horizontal prone position with legs supported and upper body unsupported (Akuthota, Ferreiro, Moore, & Fredericson, 2008).

Core Stability: the ability to control the position and motion of the trunk over the pelvis to allow optimum production, transfer and control of force and motion to the terminal segment in integrated kinetic chain activities (Kibler, Press, & Sciascia, 2006).

Core Training: a training program focused on exercises for the abdominals, paraspinals, gluteals, diaphragm, iliopsoas, and pelvic floor muscles (Akuthota, et al., 2008).

Inspiratory Muscle Training (IMT): inhalations performed against resistance using an adjustable breathing device (Weiner, Magadle, Beckerman, Weiner, & Berar-Yanay, 2003).

Maximal Inspiratory Pressure (MIP): a measure of inspiratory muscle strength; the maximal pressure that can be achieved during inhalation (Enright, Unnithan, Heward, Withnall, & Davies, 2006).

Respiratory Muscles: diaphragm, internal intercostals and external intercostals (Tortora, 2005).

Side Bridge Endurance Test: a test of the maximal time that a side bridge position can be held with correct form (Akuthota, et al., 2008).

Stabilizer Pressure Biofeedback Unit: inflatable device that shows changes in pressure, measured in mm Hg, used to measure core stability (Herrington & Davies, 2005).

Transversus Abdominis (TrA): the deepest of the abdominal muscles with the origin at the iliac crest, lumbar fascia, and cartilages of the inferior six ribs and insertion at the linea alba, xiphoid process and pubis; compresses abdomen to increase intra-abdominal pressure and stability of the spine (Tortora, 2005).

Chapter II:

Review of Literature

Introduction

This chapter contains a literature summary of core training, respiratory based exercise and the influence of exercise on respiratory muscles, and inspiratory muscle training (IMT). Core training has been shown to improve strength and stability which can be helpful in the prevention of low back pain and injury (Peate, Bates, Lunda, Francis, & Bellamy, 2007). Anatomy of the core, measurement of core function, and benefits of core training for low back pain and athletic performance are included.

Respiratory based training also influences core function. Inspiratory muscle training is known to improve respiratory muscle strength (Fregonezi, Resqueti, Guell, Pradas, & Casan, 2005) and IMT has been used for those with respiratory and muscular disorders, as well as athletes (Lima, et al., 2008; Sanchez Riera, et al., 2001). Core muscles are activated during deep breathing (Petrofsky, Cuneo, Dial, & Morris, 2005). Exercise programs that use core training combined with breathing techniques, like yoga and Pilates, improve stability and function of core muscles (Herrington & Davies, 2005).

Core Training

Core training programs have gained popularity recently and are used for many purposes. Common reasons for core training include decreasing low back pain and improving athletic performance. Core training can also be part of a full-body strength training program. Yoga and Pilates programs include core strength and stability exercises (Herrington & Davies, 2005). Core stability has been defined as the ability to control the position and motion of the trunk over the pelvis to allow optimum production, transfer and control of force and motion to the terminal segment in integrated kinetic chain activities (Kibler, Press, & Sciascia, 2006) and includes the spinal column, spinal muscles, and neural control of movement to maintain intervertebral neutral zones while performing activities of daily living (Liemohn, Baumgartner, & Gagnon, 2005).

Core Muscles. The spinal column is made up of 7 cervical vertebrae, 12 thoracic vertebrae, 5 lumbar vertebrae, the sacrum and coccyx (Hamill & Knutzen, 2003). The cervical and lumbar segments display lordosis, a curve toward the anterior side of the body. The thoracic and pelvic sections have the opposite curve of kyphosis (Hamill & Knutzen, 2003). The spine allows a considerable amount mobility despite limited range of motion at each vertebral joint (Hamill & Knutzen, 2003). The spine is the most mobile where these curves meet, making these areas most prone to injury. The cervical and lumbar curves are more mobile than the other areas of the spine.

Muscular activity in the trunk increases stability of the spine (Hodges, Eriksson, Shirley, & Gandevia, 2005). The transversus abdominis is the deepest of the abdominal muscles (Hamill & Knutzen, 2003). Transversus abdominis contraction increases intra-abdominal pressure (Hodges et al., 2005; Kibler, Press, & Sciascia, 2006) and this can occur even without contraction of other abdominal muscles (Hodges et al., 2005).

Transverse abdominis contraction occurs before the initiation of movement of the upper limbs in healthy adults (Hodges & Richardson, 1999). The diaphragm and transversus abdominis muscles are both important for posture and trunk stabilization (Hodges & Richardson, 1999). Contraction of the transverse abdominis also has been shown to occur before movement of the extremities to ensure stabilization of the spine (Akuthota, Ferreiro, Moore, & Fredericsson, 2008; Hodges & Richardson, 1999). This “feedforward” mechanism means that contractions of the transversus abdominis are initiated without feedback from limb movement (Hodges & Richardson, 1999).

In addition to providing intra-abdominal pressure, the abdominal muscles work together to decrease compression of the spine and reduce force of the trunk extensors (Hamill & Knutzen, 2003). The rectus abdominis contracts to produce trunk flexion, and runs anteriorly from the xhiphoid process and cartilage of fifth to seventh ribs to the pubic symphysis and pubic crest (Hamill & Knutzen, 2003; Tortora, 2005). Internal and external obliques produce rotation of the trunk (Hamill & Knutzen, 2003).

The iliopsoas works as a hip flexor and can create an anterior tilt in the pelvis (Hamill & Knutzen, 2003). Lateral flexion of the trunk requires contraction of muscles on both sides of the spine. Most activity during lateral flexion is in the lumbar erector spinae and deep intertransversarii and interspinales on the contralateral side (Hamill & Knutzen, 2003). Lateral flexion is also aided by the quadratus lumborum while contracted on only one side (Hamill & Knutzen, 2003).

The diaphragm makes up the upper boundary of the body's core (Tortora, 2005). When stimulated, even without co-contraction of the abdominals, the diaphragm creates intra-abdominal pressure (Hodges, Cresswell, Daggfeldt, & Thorstensson, 2001). The diaphragm contracts in preparation for movement, with the transversus abdominis, to provide spinal control (Hodges & Gandevia, 2000). Nonrespiratory activities that involve movement of the upper extremities and trunk may strengthen the diaphragm (Al-Bilbeisi & McCool, 2000).

The diaphragm and intercostal muscles are used in breathing (Tortora, 2005). Contraction of the diaphragm results in inhalation (Tortora, 2005). Also aiding in breathing are the external and internal intercostals (Tortora, 2005). Contraction of the external intercostals elevates the ribs resulting in inhalation, while contraction of the internal intercostals draws the ribs together during forced exhalation. Posture can affect the activity of abdominal muscles during respiration (Kera & Maruyama, 2005).

The posterior side of the core consists of the trunk extensors. Running the length of the spine are the erector spinae muscles, which consist of the iliocostalis, longissimus, and spinalis (Hamill & Knutzen, 2003). The deep posterior muscles, which include intertransversarii, interspinales, rotators, and multifidus, also run the length of the spine. These two groups produce trunk extension (Hamill & Knutzen, 2003). The erector spinae and multifidus provide posterior stability in order to maintain posture and control trunk flexion (Hamill & Knutzen, 2003).

The multifidus runs from the lumbar spinous processes to the sacrum, posterior superior iliac spine and erector spinae aponeurosis (Tortora, 2005). The multifidus contracts to produce lumbar spine extension and also aids in lateral flexion of the trunk (Tortora, 2005). This muscle is active in the upright position and contributes to spinal stability (Tortora, 2005).

The levator ani and coccygeus make up the pelvic floor muscles and are the most posterior part of the core (Tortora, 2005). Pelvic floor contraction also occurs with transversus abdominis and diaphragm contraction and can contribute to intra-abdominal pressure and spinal stability (Sapsford et al., 2001). Pelvic floor contractions contribute to stronger contractions of the transversus abdominis, internal and external obliques, as seen using EMG (Sapsford et al., 2001). This can occur without trunk movement and voluntary contraction of only the pelvic floor muscles.

Core Training Techniques. Core exercises contribute to the prevention of spinal instability (Akuthota, Ferreiro, Moore, & Fredericsson, 2008). Stability is influenced by muscle strength as well as nervous system responses. In order to optimize stability, both strength and coordination of core muscles should be included in a core training program (Akuthota, Ferreiro, Moore, & Fredericsson, 2008). Low load training can improve the coordination from central nervous system function and efficiency (Hibbs, Thompson, French, Wrigley, & Spears, 2008), but body weight abdominal exercises are not sufficient to improve strength (Pintar, Learman, & Rogers, 2009). Additional resistance is required for some core exercises to gain strength. High load training results in muscular hypertrophy and increases muscular strength (Hibbs et al., 2008).

Exercises done in the supine position are common and produce the lowest load on lumbar vertebrae (Axler & McGill, 1997). This load increases with activation of the abdominals and iliopsoas (Axler & McGill, 1997). The abdominal crunch and horizontal side support have been shown to produce the greatest increase in thickness of the transversus abdominis and internal oblique when compared to four other common trunk strengthening exercises (Teyhen et al., 2008).

Al-Bilbeisi and McCool (2000) compared muscle activity during sit-ups and power lifts. Sit-ups and power lifts have both been shown to increase intra-abdominal pressure and produce a strength-training effect on the diaphragm. Six subjects between the ages of 27 and 48 participated in the study. Pressures were measured using esophageal and gastric catheters in the distal esophagus (Pes) and stomach (Pga). Transdiaphragmatic pressure difference (Pdi) was calculated by subtracting Pes from Pga. A ten repetition maximum was found for each subject for the following exercises: power lift, bench press, and biceps curl. Subjects then performed 10 repetitions at approximately 33, 67, and 90% of their maximum weight. Transdiaphragmatic pressure was measured during these exercises and during sit-ups. The higher intensity power lifts were performed with and without an abdominal binder, also referred to as a weight lifting belt. Subjects were allowed three to five minutes of rest between exercises. Control subjects performed the same maneuvers without resistance. For all exercises, the diaphragm was recruited. Pdi increased as resistance increased. The highest transdiaphragmatic pressure was found during sit-ups and power lifts done at the highest intensity with the abdominal binder (Al-Bilbeisi & McCool, 2000). The intensity of these exercises was high enough to produce a strength-training effect on the diaphragm.

In a study by Hamlyn, Behm, and Young (2007), different exercises and loads were tested to determine which produced the most trunk muscle activation. Sixteen physically active subjects participated. Electromyographic (EMG) activity was measured in several muscle groups during dynamic weight training exercises, which consisted of squats and dead lifts using 80% 1RM and body weight. These exercises were compared to core stability isometric exercises, which included the superman and side bridge. Muscle groups measured included: lower abdominals, external obliques, upper lumbar erector spinae, and lumbar-sacral erector spinae. Isometric exercises were held for 30 seconds each and utilized a Swiss ball. Surface EMG electrodes were used on the muscles listed above. The squat and dead lift showed more EMG activity than those exercises performed with body weight and the stability exercises. Squats and dead lifts at 80% 1RM showed greatest muscle activity in the erector spinae. None of the four exercises showed significant difference in activation of the external obliques or lower abdominals. High intensity dynamic resistance training may produce more trunk muscle activation than stability exercises on the Swiss ball. However, stability exercises were performed without additional resistance, so less force was required to perform those exercises. High intensity dynamic resistance training produces more trunk muscle activation than stability exercises on the Swiss ball (Hamlyn, Behm, & Young, 2007). The authors state that full-body exercises performed in the upright position can have the same effect as stability core exercises and are more specific to human function and performance (Hamlyn, Behm, & Young, 2007).

Back extensor muscles are active during some core training exercises as well as squats and dead lifts (Nuzzo, McCaulley, Cormie, Cavill, & McBride, 2008). Researchers compared the activity of back extensor muscles using stability exercises and dynamic weight training. Back extension is performed during squats, deadlifts, and stability ball exercises (Nuzzo, McCaulley, Cormie, Cavill, & McBride, 2008). The nine subjects were healthy, active males, with a mean age of 23.78 years. Subjects performed a 5 minute cycling warm-up and a one repetition maximum (1RM) test was administered for the back squat and dead lift. Stability ball exercises, consisting of quadruped, pelvic thrust and ball back extension, were completed first, followed by squats and dead lifts at 50, 70, 90 and 100% of 1RM. Average integrated electromyography (IEMG) was measured at the following muscles: rectus abdominis, external oblique, longissimus and multifidus. Two trials were performed of each stability ball exercise and held for three seconds following one minute rest periods. Surface EMG was collected from the multifidus at L1 and L5 during all exercises. The rectus abdominis and external oblique activity was similar for both dynamic weight lifting and stability ball exercises. Multifidus activity at L1 and L5 was greater during squats and dead lifts at each resistance level than any of the stability ball exercises. Squats and dead lifts were more effective for muscular hypertrophy and strength in the back extensors than stability ball exercises (Nuzzo et al., 2008).

Core Measurement Techniques. It has been suggested that the evaluation of core stability should include three planes of motion, dynamic movements, and specific functional movements (Kibler, Press, & Sciascia, 2006). Core activity is used in running, kicking, throwing, and other sport skills (Kibler, Press, & Sciascia, 2006). Musculature of the core, especially the transversus abdominis, is active during extremity movements as well (Akuthota, Ferreiro, Moore, & Fredericsson, 2008; Hodges & Richardson, 1999).

There are many tests used to assess core function. The best way to measure core strength has not been determined; therefore the most useful way to use these tests is to track progress during a core training program (Akuthota, Ferreiro, Moore, & Fredericsson, 2008). A prone instability test can be conducted with the subject's chest supported on a table, with legs lowered to the floor. The subject lifts the feet off of the floor with and without support of the lumbar spine applied by the researcher. Low back pain is assessed during this test. If pain occurs without support, but not when supported, core training may be helpful for the subject. Other tests based on subject reported low back pain include single leg squat and pelvic bridging. A leg lowering test can be used to assess lower abdominal strength. Subjects are evaluated for their ability to lower the legs with control while lying in a supine position (Akuthota, Ferreiro, Moore, & Fredericsson, 2008).

The prone extension endurance test and side bridge endurance test measure the amount of time the subject can hold a position (Akuthota, Ferreiro, Moore, & Fredericsson, 2008) and these tests require little to no equipment and are easily performed. However, subject motivation and effort are limiting factors for these tests and limit the reliability (Moreau, Green, Johnson, & Moreau, 2000).

A pressure biofeedback unit, or Stabilizer, placed under the lumbar curve of the spine with the subject in a supine position can measure lumbar stability (Herrington & Davies, 2005, Stanton, Reaburn, & Humphries, 2004). Deep abdominal muscle function can also be assessed using the Stabilizer by teaching subjects a drawing in maneuver and measuring the change in pressure. Using a test-retest design, Storhiem and colleagues (2002) found a coefficient of variation of 21.0 percent (standard deviation 1.59) between pre and post testing. Subjects with low back pain were shown to not perform as well as healthy subjects on this test (Caims, Harrison, & Wright, 2000). Caims and colleagues (2000) found this test to be a useful tool to measure of deep abdominal function in both subject populations.

Core Training for Improved Performance. Core stability training does not significantly increase athletic performance, though it is commonly used for this purpose (Akuthota, Ferreiro, Moore, & Fredericsson, 2008). Some researchers suggest that reducing low back pain and injury through core training improves performance by allowing the athlete to miss less playing time due to injury (Hides, Stanton, McMahon, Sims, & Richardson, 2008). Lack of evidence for core strengthening programs to improve performance may be due to a lack of a gold standard for measuring core strength and stability (Hibbs, Thompson, French, Wrigley, & Spears, 2008).

Stanton, Reaburn, and Humphries (2004) investigated the effect of Swiss ball exercises on spinal stability and running economy. Eighteen young male athletes were divided into control or experimental groups. The experimental group performed two Swiss ball trainings per week for six weeks. Training consisted of the following exercises on the Swiss ball: lunge, supine lateral roll, alternating superman, forward roll on knees, supine 2-leg bridge, and supine Russian twist. Core stability was assessed using a Swiss ball prone stabilization core stability test and a clinical assessment. The clinical assessment of core stability, the Sahrmann test, was performed using the inflatable pad of a Stabilizer Pressure Biofeedback Unit under the lumbar curve while the subject was lying supine with knees bent to 90 degrees and feet flat on the floor. Movements of the lower extremity were performed including hip flexion and extension at various angles. To move to the next level of the test, subjects must complete these movements with less than

10mmHg difference in pressure of the pad under the lumbar curve. Performance on core stability measures did improve, but these improvements did not impact performance on other exercise tests. No improvements in running performance were observed. Stability training did not improve VO_2 max, running economy or upper body position during running (Stanton, Reaburn, & Humphries, 2004).

Core stabilization training may affect the severity of low back pain in cricketers (Hides et al., 2008). Twenty-six elite male cricket players were divided into two groups based on their history of low back pain. Those with low back pain were assigned to the training group, those without in a control group. Training consisted of stability exercises starting in the supine position, and consisted of learned contraction of transversus abdominis, multifidus, and pelvic floor muscles. Training progressed to seated and standing exercises. For multifidus endurance, subjects were instructed to lean forward from the hips and hold the position. Weight was added as strength and endurance increased. An imaging system was used to provide visual feedback for subjects on exercise form. The results of this study showed that all subjects with low back pain reported a decrease in pain after the stability training. Multifidus cross sectional area was measured after stabilization training. Stabilization training increased multifidus cross sectional area and decreased asymmetries in cricketers with low back pain. Despite high fitness levels, specific training was needed to improve multifidus strength and reduce low back pain (Hides et al., 2008).

Myer and colleagues (2005) researched the role of core training on athletic performance when combined with other sport specific training. A four-component neuromuscular training program showed significant improvements on athletic performance in young female athletes (Myer, Ford, Palumbo, & Hewett, 2005). The training program consisted of core stability and balance, plyometrics, resistance training, and speed training. Core strength and balance exercises consisted of broad jumps, box drop medicine ball catches, and several exercises done using the BOSU ball including crunches, V-sits, superman, double-leg perturbations, and single-leg deep hold. Fifty-three female high school athletes participated and forty-one of the subjects were assigned to the training group and 12 served as controls. Supervised training sessions were conducted three times per week for 90 minutes and performance was evaluated using vertical jump height, sprint time, single-leg hop-and-hold distance and strength testing. Motion analysis was also conducted to observe impact on lower-extremity injury risk. The training group improved both strength and vertical jump height. Medial-lateral knee torques on landing were reduced after the training program indicating a lower risk of knee injury, with no changes observed in the control group. This multi-component training showed an improved performance and decreased risk of injury in high school level female athletes (Myer et al., 2005). However, the contribution of core strength and stability is unknown. Improvements in core function were not directly evaluated. Including a core stability and strength component may enhance performance, but the mechanisms of this are unclear.

Szymanski and colleagues (2007) tested the effects of medicine ball exercises for the torso on rotational strength and power in high school baseball players. All athletes participated in a 12 week off-season strength training program and performed 100 bat swings three days per week. Half of the athletes added rotational medicine ball exercises to the training program. Medicine ball exercises included a standing figure 8 exercise where the medicine ball was passed between two athletes standing back to back, a hitters throw in which the athlete rotates the trunk and releases the ball with maximum force, and a standing side throw. Torso rotational strength was measured using a hitter's throw test which measured the maximum distance the ball traveled. The group participating in the medicine ball exercises improved torso rotational strength significantly more than the group that did not. Bat swing velocity was not measured in this study, but the authors assert that increased rotational power will increase bat velocity (Szymanski, Szymanski, Bradford, Schade, & Pascoe, 2007).

Although core training may improve bat speed, there is not clear evidence that a core training program will improve sports or exercise performance. More evidence is needed to differentiate the results of core stability training and an overall resistance training program (Akuthota, Ferreiro, Moore, & Fredericsson, 2008).

Respiratory Based Exercise

Exercises for the respiratory system can include specific breathing exercises, yoga and Pilates, or high-intensity exercise which causes heavy breathing. Yoga and Pilates incorporate breath with movements (Herrington & Davies, 2005). Exercise training, even without specific breathing training, can improve respiratory function as well (Murphy & Watsford, 2005).

Yoga and Pilates. Yoga and Pilates are becoming more popular modes of exercise. These programs incorporate core stability, strength and breathing exercises into fitness. Combining these may have additional benefits for core, respiratory muscle strength and endurance, and spinal stability (Herrington & Davies, 2005).

Herrington and Davies (2005) examined subjects' ability to contract the transversus abdominis (TrA), which provides spinal stability. Thirty-six female subjects were divided into three groups: a Pilates training group, an abdominal curl-up group, and a non-training control group. Pilates classes were 45 minutes long; abdominal curl-up classes were 15 minutes. Subjects participated in classes once or twice a week for six months. A TrA isolation test was given using a pressure biofeedback unit (PBU). Subjects lay in the prone position and were instructed to draw in the abdomen without moving the trunk or pelvis and hold the contraction with normal breathing for 10 seconds. To pass the test, a drop of 6 mm Hg was required. A lumbo-pelvic stability test also provided information on TrA contraction with limb movement. Subjects started lying in a supine position with knees bent at 90 degrees and feet on the floor, and moved one leg to 90 degrees of hip flexion with the PBU under the lumbar portion of the spine. In order to pass, the pressure was required to remain at 40 mmHg. Out of the 12 subjects in each group, 10 (83%) from the Pilates group, four (33%) from abdominal curl group and three (25%) from the control group passed the TrA isolation test. Only five subjects from the Pilates group, and none from the other two groups, passed the lumbo-pelvic stability test. The Pilates trained subjects were shown to be more likely to properly contract the TrA and maintain stability in the spine (Herrington & Davies, 2005). Pilates training may elicit better neuromuscular recruitment patterns than training abdominal curls alone.

Petrofsky and colleagues (2005) designed a study to determine how yoga breathing can affect muscle activity of the rectus abdominis and external obliques compared to abdominal crunches. Twenty-nine subjects performed both activities while muscle activity was measured using EMG. The breathing exercise consisted of deep yoga breathing in a seated position. Subjects performed slow exhalation through the mouth and quick inhalation through the nose, then exhaled through the mouth rapidly using the abdominal muscles. Following the exhale, the mouth was closed and abdominal contraction was held for an average of six seconds. EMG activity was greater during the seated breathing exercise than during abdominal crunches (Petrofsky, Cuneo, Dial, & Morris, 2005). The authors suggested that this activity can work to strengthen abdominal muscles for people uncomfortable getting into the supine position on the floor.

One study shows that the benefits of yoga and Pilates go beyond physical strength measurements (Donesky-Cuenco, Nguyen, Paul, & Carrieri-Kohlman, 2009). Forty-one subjects over 40 years old with dyspnea impairing performance in activities of daily living were divided into a control or yoga training group. The yoga group participated in two one-hour classes per week and were encouraged to practice at home. Yoga classes were specially designed for dyspnea treatment and included *pranayama* breathing techniques. Although dyspnea distress decreased, there was no change in the intensity of dyspnea or in the subjects' pulmonary function. Yoga decreased dyspnea distress and improved functional performance in older adults with Chronic Obstructive Pulmonary Disease (COPD) demonstrating that these patients may benefit from yoga training as a compliment to usual care (Donesky-Cuenco et al., 2009). COPD patients also displayed an increase in oxygen saturation immediately following yoga breathing exercises (Pomidori, Campigotto, Amatya, Bernardi, & Cogo, 2009).

In addition to muscular activity, yoga breathing exercises have also been shown to have an effect on cardiorespiratory function (Upadhyay-Dhungel, Malhotra, Sarkar, & Prajapati, 2008). Thirty-six sedentary subjects performed alternate nostril breathing, the *Nadisudhi Pranayama* in yoga, for 15 minutes each day for four weeks. No control group was included in this study. Training showed positive effects on cardiorespiratory function in healthy young adults. These included a decreased pulse rate, respiratory rate, and diastolic blood pressure (Upadhyay-Dhunge et al., 2008).

Nonrespiratory exercise. In a study of 25 community dwelling adults over the age of 65 years, Summerhill and colleagues (2007) found that those who led active lifestyles had significantly greater maximal inspiratory pressures, maximal expiratory pressures, and diaphragm muscle thickness than those who were inactive. Subjects were categorized in the "active" group if they participated in at least 30 minutes of vigorous activity three or more times a week. Active subjects had nearly double the maximal inspiratory pressures of those subjects who fell below this level of activity. Physical activity, without respiratory muscle training, can improve and maintain respiratory muscle strength (Summerhill, Angov, Garber, & McCool, 2007).

Eight fit males participated in a study on how resistance training affects the respiratory muscles (DePalo, Parker, Al-Bilbeisi, & McCool, 2004). Subjects were divided into a training group and a control group. The training group participated in a resistance training program of sit-ups and bicep curls. Training was done four times per week for 16 weeks. This program elicited significant increases in diaphragm thickness and maximal expiratory and inspiratory pressures, however each group had only four subjects. Resistance training of the trunk and upper extremities can have a strength-training effect on respiratory muscles, including the diaphragm (DePalo, Parker, Al-Bilbeisi, & McCool, 2004). The results of this study validate Summerhill and colleagues' (2007) findings that active adults had greater respiratory muscle strength.

Heavy breathing during exercise. During vigorous physical activity, respiratory rate and tidal volume increase (Tortora, 2005) and this increased workload for respiratory muscles may result in higher levels of strength in the physically active compared to inactive (DePalo, Parker, Al-Bilbeisi, & McCool, 2004; Summerhill et al., 2007). This can also increase thickness of the diaphragm (Summerhill et al., 2007).

Intensive swim training has also been shown to have similar effects on respiratory measures as inspiratory muscle training (IMT) (Mickleborough, Stager, Chatham, Lindley, & Ionescu, 2008). In an experiment of 30 swimmers participating in a 12-week intensive training program, subjects were divided into three groups. The training group performed IMT at 80% sustained maximal inspiratory pressure (SMIP), 3 days per week. One group performed sham IMT at 30% SMIP, and the third group served as controls. All 30 swimmers participated in the same swim training program. All three groups had similar improvements in respiratory values at the end of the 12 week program. All groups showed a significant increase in MIP, power output, inspiratory muscle endurance and expiratory muscle strength (Mickleborough et al., 2008). Adding IMT to a swim training program did not show any additional benefits over swim training alone. Improvement in respiratory strength and endurance can be achieved through breathing patterns and training programs used by competitive swimmers.

Well trained cyclists were tested for the effect of respiratory muscle work on exercise performance (Harms, Wetter, St Croix, Pegelow, & Dempsey, 2000). Seven competitive male cyclists, average age 27.3 years, participated in this study. Maximal oxygen consumption was measured for each subject during an incremental maximal cycling test. Three submaximal trials were performed at 90% VO_{2max} with normal inspiratory conditions, inspiratory loading and inspiratory unloading. A proportional-assist ventilator (PAV) was used during the inspiratory unloading test to reduce work of the respiratory muscles and during the loading test to increase workload. The three trials were conducted over a 6 to 8 week period. Under the respiratory unloading condition, subjects were able to exercise an average of 1.3 minutes longer than the control condition. Respiratory loading decreased time to fatigue compared to the control condition by one minute (Harms et al., 2000). This research indicates that respiratory work has a significant impact on exercise performance in well-trained subjects. Decreasing respiratory work can improve exercise tolerance at high intensities, while increasing respiratory work has a detrimental effect on exercise tolerance.

Murphy and Watsford (2005) investigated the effect of walking training on respiratory muscle function and performance. Twenty-six women, aged 60 to 69 years, participated. Subjects were divided into a walking training group or a control group. The training group performed three walking sessions per week for eight weeks at 60% of heart rate reserve. The training group showed greater improvements in respiratory muscle strength measured by maximal inspiratory pressure and maximal expiratory pressure. On the incremental treadmill walking test, the training group showed a reduction in working heart rate and an increase in time to exhaustion (Murphy & Watsford, 2005). Improved respiratory muscle strength may result in a greater tolerance of higher exercise workloads.

The strength of inspiratory muscles can be increased through core training and high-intensity exercises which cause heavy breathing (Al-Bilbeisi & McCool, 2000, Murphy & Watsford, 2005). Similar results can be achieved through inspiratory muscle training (Downey et al., 2007; Johnson, Sharpe, & Brown, 2007; Sanchez Riera et al., 2001).

Inspiratory Muscle Training.

Inspiratory muscle weakness may limit exercise performance (Hamilton, Killian, Summers, & Jones, 1995). Inspiratory muscle training (IMT) has been shown to improve strength and endurance of respiratory muscles (Downey et al., 2007; Johnson, Sharpe, & Brown, 2007; Sanchez Riera et al., 2001). IMT can also increase thickness of the diaphragm (Enright, Unnithan, Heward, Withnall, & Davies, 2006).

Use of inspiratory muscle training with diseases. IMT is often used in people with diseases such as Chronic Obstructive Pulmonary Disease (COPD) and asthma (Lima, et al., 2008; Sanchez Riera, et al., 2001). Improving inspiratory muscle strength in these populations can improve patients' independence, performance of activities of daily living, and quality of life (Lima et al., 2008; Sanchez Riera et al., 2001).

Inspiratory muscle training at home over six months had positive effects on patients with COPD including improved respiratory muscle function, exercise performance and decreased dyspnea (Sanchez Riera et al., 2001). Twenty COPD patients participated in this study. A training group performed IMT at 60-70% maximal sustained inspiratory pressure (SIPmax) which is equal to approximately 30% of MIP, 30 minutes a day, six days a week for six months. The training was performed at home with an incentive flowmeter with visual feedback. Inspiration lasted 1.5 to 2 seconds; expiration lasted 6 seconds. A control group performed this technique with zero load. After training, patients in the training group reported improved quality of life on the health related quality of life questionnaire (Sanchez Riera et al., 2001).

IMT causes structural and physiological changes in external intercostal muscles in patients with chronic obstructive pulmonary disease (COPD) (Ramirez-Sarmiento et al., 2002). In this study, fourteen sedentary males who had been diagnosed with COPD were randomly assigned to IMT or control groups. IMT was performed for 30 minutes, five days per week for five weeks. Training was done at 40-50% of initial maximal inspiratory pressure. The control group completed the same training at a sham intensity. Biopsies were taken on the external intercostals and vastus lateralis prior to and following the training. The IMT group improved inspiratory muscle strength and endurance. Ramirez-Sarmiento and colleagues (2002) also found that IMT increased the proportion of type I fibers and increases the size of type II fibers in external intercostal muscles.

A similar study found that specific IMT produces the same benefits in COPD patients as combining IMT and specific expiratory muscle training (Weiner, Magadle, Beckerman, Weiner, & Berar-Yanay, 2003). Thirty-two COPD patients were divided into four groups. One group performed specific expiratory muscle training (SEMT) with sham IMT, one performed specific IMT with sham EMT, one performed both specific IMT and specific EMT, and the fourth served as controls, performing sham levels of both conditions. Sham levels were consistent for both conditions at 7cmH_2O. Training was performed one hour a day, six days per week for three months. Intensity progressed from 15% MIP or MEP to reach 60% MIP and/or MEP by the end of the first month. No significant change in spirometry values was found for any of the groups. All three training groups improved on MEP and MIP, with no significant difference in improvement between the groups. Improvements were found in expiratory muscle endurance in the SEMT group and the group that performed both EMT and IMT, but not in the IMT group or control group. Similar results were found for inspiratory muscle endurance. The IMT and combined training groups improved, while the SEMT and control did not. Patients in all three training groups had small but significant increases in distance walked in the 6 minute walk test, while the control group did not improve performance. This study showed no benefit of performing EMT combined with IMT over training inspiratory muscles alone (Weiner, Magadle, Beckerman, Weiner, & Berar-Yanay, 2003). Improvements in exercise performance were observed as a result of respiratory muscle training in patients with COPD.

Lima and colleagues (2008) investigated the effect of inspiratory muscle training on asthma symptoms. Fifty children aged 8 to 12 years with uncontrolled asthma participated in the study. Subjects were randomly assigned to control or IMT groups. The IMT group trained at 40% MIP, 50 minutes twice per week for 7 weeks. The first half of each session was spent doing exercises in supine position including diaphragmatic breathing and pursed-lip breathing followed by IMT for the last 25 minutes. Routine medical visits and an educational program on asthma were utilized for both groups. The results of this study demonstrated that IMT can improve the efficiency of respiratory muscles in children with asthma, decreasing the severity of the condition (Lima, et al., 2008). Severity was measured by frequency of asthma attacks, nocturnal symptoms, ability to perform ADLs, hospitalization and emergency room treatment. Respiratory muscle strength was measured using maximal inspiratory pressure, maximal expiratory pressure, and peak expiratory flow, which all showed significant improvement over seven weeks of IMT training (Lima et al., 2008).

Patients with myasthenia gravis participated in an IMT training program designed to improve muscle strength and quality of life (Fregonezi, Resqueti, Guell, Pradas, & Casan, 2005). Twenty-seven stable myasthenia gravis (MG) patients, under 75 years of age, with no other disease that would interfere, were randomly assigned to a training or control group. Training consisted of 8 weeks of interval-based IMT combined with diaphragmatic breathing and pursed lips breathing. This was practiced 3 times per week in 45 minutes sessions which included 10 minutes of diaphragmatic breathing, 10 minutes of inspiratory muscle training, and 10 minutes of pursed lips breathing with 5 minute breaks between each exercise. IMT progressed throughout the study, starting at 20% MIP, increasing to 30% at third week, 45% at fifth week, and 60% at seventh week. Results for the training group showed spirometry values and lung volumes unchanged, a decrease in respiratory rate by 14%, a significant increase in maximal inspiratory pressure by 27% compared to baseline. An increase in maximal expiratory pressure of 12%, although there was no training of expiratory muscles, was also observed. Maximal voluntary ventilation increased by 8%. Chest expansion and reduction also increased, and a 44% improvement was found for the training group on the quality of life questionnaire. After 8 weeks of IMT training, MG patients showed improvement in respiratory muscle strength and self reported quality of life (Fregonezi et al., 2005).

Athletic Performance. Studies of the effect of inspiratory muscle training on exercise performance have shown inconsistent results (Downey et al., 2007, Johnson, Sharpe & Brown, 2007, Nicks, Morgan, Fuller, & Caputo, 2009, Watsford & Murphy, 2008). It has been hypothesized that IMT can improve maximal oxygen consumption, sprint performance, and time to exhaustion. Respiratory muscle fatigue increases perceptions of effort in high intensity, sustained exercise (Romer & Polkey, 2008). Decreasing this fatigue may increase time to exhaustion and show improvements in performance without improvements in oxygen consumption (Romer & Polkey, 2008).

McConnell and Lomax (2006) investigated the effect of inspiratory muscle work and IMT on fatigue of plantar flexor muscles. Subjects were made up of seven women and one man. All subjects exercised at least three times per week for a minimum of 45 minutes and were free of cardiovascular and respiratory disease. The subjects performed seven different experiments, performing plantar flexion under different conditions. Plantar flexion isokinetic force was measured using an isokinetic dynamometer. Two of these experiments were performed after four weeks of IMT. IMT consisted of 30 breaths, twice each day, at approximately 50% of MIP. Prior to any IMT, the calf muscles showed a shorter time to fatigue following an inspiratory muscle fatigue task. This same trial done after four weeks of IMT showed no increase in fatigue of calf muscles. This indicates that inspiratory muscle work decreases leg fatigue. Training of inspiratory muscles can reduce fatigue of plantar flexor muscles during extended contraction, which may be due to the decrease in required blood flow to the respiratory muscles. This suggests that inspiratory muscle training can decrease the rate of fatigue of other muscles used during exercise (McConnell & Lomax, 2006).

Studies show that IMT improved performance on submaximal tests, despite the lack of increase in oxygen consumption (Edwards, Wells, & Butterly, 2008; Williams, Wongsathikun, Boon, & Acevedo, 2002). The evidence that IMT does not increase VO_2 max is likely due to the lack of whole body work with IMT.

Nicks and colleagues (2009) tested the effects of a respiratory training program on intermittent running performance. Subjects consisted of 30 NCAA Division I soccer players, mean age 19.8 (SD .9). Subjects were randomly divided into a respiratory muscle training (RMT) group or a control group. Respiratory muscle training was performed for 5 weeks, 5 days per week, 2 times per day. Each session consisted of 30 repetitions at ~50% of maximal inspiratory pressure. RMT resistance increased 1-2 times per week to maintain training at a 30 repetition maximum. Training sessions were supervised as much as possible and training logs used when they were unable to be supervised. An auditory pacer test was used to measure the impact on running performance. Maximal inspiratory pressure was measured 2 and 10 minutes after completion of this test to measure respiratory muscle fatigue. The RMT group showed a significant increase in maximal inspiratory pressure of 20%. Performance on the running test increased by 17%. No differences in dyspnea ratings were observed between groups. RMT improved performance on the pacer test, indicating an improved performance in intermittent running seen in soccer and other sports. Improvements in maximal inspiratory pressure may result in decreased respiratory fatigue (Nicks, Morgan, Fuller, & Caputo, 2009).

Another study used a similar training intensity, but a shorter training duration, to determine if improvements would be made on submaximal running performance (Downey et al., 2007). Fifteen non-smoking subjects with normal pulmonary function test scores were separated into IMT and control groups. Training consisted of 40 maximal inhalations from residual volume, twice a day, 5 days per week for 4 weeks. IMT was performed at 50 percent of MIP. The control group performed the same training protocol at 15% MIP. Diaphragm thickness, measured using ultrasound, during maximal inspiratory pressure test increased significantly in the IMT group. The IMT group also improved maximal inspiratory pressure significantly by 24.5%. Respiratory muscle endurance was unchanged for both groups. Subjects' performance on a treadmill test at 85% VO_{2max} did not improve after four weeks of IMT. There was also no effect on blood lactate levels, however at hypoxic levels the IMT group had improved ventilatory response and gas exchange. This study indicates that four weeks of IMT is not sufficient to improve submaximal running performance (Downey et al., 2007).

Edwards and colleagues (2008) performed research on a combined program of IMT with cardiovascular training. Sixteen males participated in a running training program three days per week for four weeks. One group performed IMT in addition to the running. Both groups showed improvement in maximal inspiratory pressure, with the IMT group showing a significantly greater increase and the IMT group also decreased their rating of perceived exertion during the 5000 meter run test. Although VO_{2max} and maximal heart rate did not improve, the IMT group improved their time on the 5000 meter run significantly more than the control group (Edwards, Wells, & Butterly, 2008).

Johnson, Sharpe, and Brown (2007) studied the role of inspiratory muscle training on cycling time-trial performance. Inspiratory muscle training was performed twice a day for six weeks. Subjects performed 30 maneuvers at approximately 50% of maximal inspiratory pressure. Training load was increased periodically to produce a maximal effort to complete 30 maneuvers. Each inspiration was initiated at RV with the goal of maximizing tidal volume. The placebo group used a device that was identical to the IMT trained for 15 min, 5 days per week. Subjects were told to breathe normally while using this device. Both groups participated in the same cycling training program. Maximal inspiratory pressure increased (17.1%) in IMT group throughout the six week study and remained unchanged for the placebo group. Time to complete 25 kilometers decreased by 2.66+-2.51% in the IMT group and remained constant in the placebo group. An increased aerobic work capacity was observed. This was seen as a significant decrease in time to complete the 25 kilometer cycling time-trial (Johnson, Sharpe, & Brown, 2007).

Gething and colleagues (2004) examined the effects of different inspiratory muscle training intensities on cycling performance (Gething, Passfield, & Davies, 2004). Sixty-six subjects were divided into three groups with varying intensities for inspiratory muscle training. One group trained at 100% maximal inspiratory pressure (MIP), one at 80% MIP, and the control group received no training during the 6 week study.   Both training groups had greater improvement in inspiratory strength, measured by MIP, than the control group. The maximal training group showed significant decreases in heart rate and rating of perceived exertion during a five minute constant load cycling bout (Gething, Passfield, & Davies, 2004). Decreased exertion during exercise may have resulted from decreased fatigue of respiratory muscles.

In a study by Riganas and colleagues (2008), well trained rowers performed IMT 30 minutes per day, five days a week for six weeks. Significant improvements were found in MIP at rest (28%) and after completing a maximal VO_2 test (Riganas, Vrabas, Christoulas, &

Mandroukas, 2008). This finding showed increases in inspiratory muscle strength and endurance. No improvement was found in VO_2 max or 2000 meter rowing time.

Another study by Williams and colleagues (2002) examined the effects of inspiratory muscle training on running endurance. Seven collegiate distance runners participated in a 4 week IMT program. Training consisted of 25 minutes per day, 4 to 5 days per week at 50-65% MIP. Inspiratory strength and endurance significantly increased after training. Heart rate and VO_{2max} did not change as a result of training (Williams, Wongsathikun, Boon, & Acevedo, 2002). The results of this study suggest that IMT did not affect distance running performance in endurance athletes.

Klusiewicz (2008) tested the effect of IMT on rowing performance. Fifteen elite male rowers were separated into training and control groups. The training group received IMT for 6 weeks while the control group received no training in addition to rowing practices. IMT consisted of 30 repetitions twice per day at 60% MIP. No change in VO_{2max} was observed in either the experimental or control group. The IMT group also showed a 34% increase in MIP. The control group had no significant increase in MIP (Klusiewicz, Borkowski, Zdanowicz, Boros, & Wesolowski, 2008).

A study using respiratory muscle training (RMT) investigated the role of respiratory muscle fatigue on underwater swimming. Thirty male subjects, mean age 23.4 years, participated in this study. All were experienced swimmers and underwent SCUBA training prior to the study. Subjects were tested before and after RMT for pulmonary function, maximal inspiratory and expiratory pressures, residual volume, and total lung capacity. VO_{2max} was also measured during a swim test. Subjects completed an underwater endurance swim test which was performed until the subject could no longer maintain the pace required. Subjects were randomly divided into three groups. One group performed endurance RMT, one resistance RMT, and one performed sham training and served as the placebo group. The placebo training was performed without resistance. The resistance RMT group performed one breath every 30s and breathed normally for the remainder of the time. The endurance RMT group performed RMT for the entire 30 minutes at approximately 55% of the subject's sustained vital capacity. Training was done for 30 minutes per day, five days per week for 4 weeks. One session per week was supervised by the investigator. The placebo group showed no significant change in any test. The resistance RMT improved performance on underwater swimming, improving time to exhaustion by 66 percent. The resistance RMT group also had the greatest improvement in maximal inspiratory pressure. Respiratory muscle fatigue was a limiting factor in underwater swim performance and can be improved by respiratory muscle fatigue (Wylegala, Pendergast, Gosselin, Warkander, & Lundgren, 2007). Respiratory muscle training (RMT) increased tidal volume, maximal inspiratory and expiratory pressures, time to exhaustion, and decreased breathing frequency during underwater swimming (Wylegala et al., 2007).

Inspiratory muscle training affects the cardiorespiratory system which may have implications for whole body exercise. Inspiratory muscle training reduces heart rate responses and rises in mean arterial pressure when performing a resistive breathing task (Witt, Guenette, Rupert, McKenzie, & Sheel, 2007). If IMT can slow physiologic responses of the cardiovascular system, this may result in improved performance in endurance exercise (Witt et al., 2007). IMT can affect exercise by lowering working heart rate, decreasing perceived exertion, and lowering respiratory rate (Gething, Passfield, & Davies, 2004). Although these results do not translate to improved VO_{2max}, they have been shown to improve time trial performance in cycling and intermittent running (Johnson, et al., 2007, Nicks, et al, 2009). Improvements in maximal inspiratory pressure are consistent, but, with the exception of endurance performance, the relation to sports performance is not substantially supported (Downey et al., 2007).

Summary

More research is needed to investigate the mechanisms for improved exercise performance following inspiratory muscle training (IMT). IMT strengthens respiratory muscles, including the diaphragm, which helps to control intra-abdominal pressure (Akuthota, et al., 2008). This increase in strength may produce similar results to core training techniques. If benefits of core training can be achieved through breathing exercises, such as IMT, core function can be improved in those who are unable to do traditional core training exercises, or possibly as an addition to a core training program to maximize results.

Chapter III:

Methods and Procedures

Introduction

This study tested the hypothesis that inspiratory muscle training (IMT) would result in increases in core stability. Results from IMT were compared to a core training program focusing on abdominal musculature. Descriptions of the study population, design, training, and data collection are included in this chapter.

Description of Study Population

The population used in this study consisted of Western Washington University students. Subjects in the core training group were participating in "AbLab" group fitness classes offered at the student recreation center. Subjects in the IMT and control groups consisted of volunteers who were not currently participating in a core training program.

Design of the Study

The design was a three group repeated measures design to study core function. Forty subjects were selected from volunteers to the IMT and control groups. Supervised IMT was performed Monday through Friday for six weeks. Subjects performed IMT at approximately the same time of day for the duration of the training. Each session of IMT lasted 10 to 15 minutes totaling approximately 60 minutes per week. Data was excluded from subjects who attended fewer than 90 percent of the training sessions, which was equal to missing more than three training sessions. Subjects in the core training group were selected from AbLab classes. Subjects in this group were required to attend class twice per week during the duration of the study. Attendance was recorded for each class. Less than 90 percent attendance to the classes or more than one absence from class excluded these subjects' data from the results. Pre and post test data were compared for these two training groups and a control group which received no training.

Data Collection Procedures

Risks and benefits of participation in the study were explained and informed consent was obtained from each subject. The Human Subjects Committee at Western Washington University approved this study.

Instrumentation. Maximal inspiratory pressure (MIP) was measured using a device engineered at Western Washington University by Scientific Technical Services. MIP was measured at the beginning of each week of training for the IMT group. The IMT training device used was an adjustable Powerbreathe (Southam, Warwickshire, UK) with the workload set at 80% of each subject's MIP. Transversus abdominis function was tested using a pressure biofeedback unit (Stabilizer, Chattanooga Group, Hixson, TX) which consists of an inflatable pad which measures change in pressure.

Measurement techniques and procedures. Tests of core function included a timed prone extension endurance test, side bridge endurance test, and a test of transversus abdominis function. During the prone back extension endurance test, the subject's lower extremities were supported and the subject held the upper body in a position parallel to the floor. During the side bridge test, the subject supported their body on one hand and the same side foot with the spine in a straight, neutral position. If a subject was unable to perform this position, a modified side plank was performed. During the modified side plank, the subject's forearm is used instead of the hand. Subjects chose their preferred side for this test. Maximal times for the endurance tests were recorded in seconds. Subjects were timed while holding the position. Breaking from the correct position ended the test.

The test of transversus abdominis (TrA) function measured the change in pressure during TrA contraction. Subjects began the test lying prone on a flat surface. The Stabilizer (Chattanooga Group, Hixson, TX), an inflatable pad similar to a blood pressure sphygmomanometer, was positioned under the abdomen and inflated to 70 mm Hg. The subject was instructed to breathe normally while the pressure stabilized. Subjects were instructed to raise the abdomen away from the pad without appreciably moving the spine or pelvis and hold that position for 5 seconds. Change in pressure was recorded from the Stabilizer unit dial. A negative change in pressure indicated a contraction of the TrA. An unsuccessful test resulted in no change in pressure or a positive change. One practice test was performed, followed by three trials. The highest negative pressure value or lowest positive value of the three was used as the subject's score.

The test of maximal inspiratory pressure (MIP) was conducted during pre and post testing for the core training and control groups and weekly for the IMT group. Subjects performed the maneuver standing, wearing a noseclip. Subjects were instructed to perform a maximal exhalation to residual volume, close valve by turning handle to horizontal position, then perform a maximal forced inhalation. This procedure was repeated two times allowing at least 30 seconds rest between each measurement. The highest value was recorded in cm H_2O.

Training Program Description. Subjects in the IMT group performed IMT under supervision of the researcher. Five sets of 12 repetitions were performed with a Powerbreathe (Southam, Warwickshire, UK) device each session. IMT was performed once per day, Monday through Friday for 6 weeks in the Exercise Physiology laboratory at Western Washington University. Intensity was set at 80% MIP and was adjusted based on gains in MIP as training progressed. MIP was tested at the beginning of each week to maintain training intensity at 80%.

The core training group participated in 30 minute group fitness classes twice per week which focused on abdominal muscles for six weeks. Typical exercises consisted of various supine curl-ups, crunches, and stability ball exercises and are listed in Appendix C. The control group did not participate in any training and was tested at the same times as the IMT and core training groups.

Data Analysis

Mean and standard deviations were calculated for each group for MIP, Stabilizer pressure measurements, and maximal times for prone extension and side bridge. A two-way repeated measures mixed analysis of variance (ANOVA) was performed with the factors group and time using SPSS (Version 12, Chicago, IL). Group had three levels (IMT, Core Training, and Control) and time had two levels (pre- and post-intervention). If a significant change was found, post hoc analysis was performed. Alpha level was set at less than 0.05.

Chapter IV

Results and Discussion

Introduction

The purpose of this study was to investigate the effects of inspiratory muscle training (IMT) on core muscle function compared to a typical core training program. IMT and core training were performed by separate groups for six weeks. A third group served as controls. Respiratory function and the function of the core muscles were assessed before and after the training period.

Characteristics of the Subjects

Research subjects were Western Washington University students who voluntarily participated in the research. All subjects completed an informed consent form before participating. Inspiratory muscle training (IMT), core training, and control groups started with 15 subjects. Subjects in all groups were free of any low back pain or injury. IMT and control subjects were not currently participating in a core training program.

Five subjects in the IMT group and three in the core training group did not complete the training and were excluded from the study. Five control subjects failed to return for post-testing. Data is reported for 10 IMT subjects (5 male, 5 female), 12 core training subjects (all female), and 10 control subjects (3 male, 7 female) as shown in Table 1. There was no difference in age, height or body mass index between the three groups, but the IMT group had a greater body weight. This was likely due to the greater number of male subjects.

One core training subject elected not to participate in the prone extension test following training, and was excluded from data for that test. One subject performed the Stabilizer test of transversus abdominis contraction with an abnormally high score of over four standard deviations above the mean and was also excluded from the data on that test. This subject performed an abdominal outpouching during the test. An abnormal breathing pattern may have contributed to this score.

Table 1. Description of the Study Population

Group	Age (years)	sd	Weight (kg.)	sd	Height (cm.)	sd	BMI (kg/m2)	sd
IMT	21.8	1.7	78.1	8.5	178	7.8	24	2.1
Core	19.7	1.5	61.5	9.8	164	4.8	22.9	3.1
Control	22.7	1.4	62.5	7.7	167	7.3	22.2	1.9

IMT=Inspiratory Muscle Training; Core=Core Training; sd=standard deviation; kg.=kilograms; cm.=centimeters; BMI=Body Mass Index; no significant differences between groups

Results

There was no change in body weight over the six weeks of training. The three day diet and physical activity records also showed no difference between groups at baseline and no change over the training period. Mean kilocalorie intake at the beginning of the study was 1865 kilocalories for all subjects. Mean intake at the end was 1805 kilocalories. Means and standard deviations for each group are reported in Table 2. Energy expenditure also showed no significant difference between groups or for any group over the six week training period. Mean energy expenditure at the beginning of the study was 2919 kilocalories and 2860 kilocalories at the end for all subjects.

Table 2. Energy Intake and Expenditure

	Pre-Test				Post-Test			
Group	**Intake (kcal/day)**	**sd**	**Expend. (kcal/day)**	**sd**	**Intake (kcal/day)**	**sd**	**Expend. (kcal/day)**	**sd**
IMT	1977	498	3264	431	1960	396	3207	466
Core	1896	406	2644	376	1826	436	2679	399
Control	1747	402	2892	670	1627	353	2761	510

IMT=Inspiratory Muscle Training; Core=Core Training; Expend= Energy Expenditure; kcal=kilocalories; no significant differences

Side Bridge. On the side bridge test, there was no significant interaction. All three groups showed a significant increase in time on the side bridge test (F=11.597, p=0.002). Means and standard deviations for each group are listed in Table 3. The mean time on the pre-test for the IMT group was 71.0 seconds. Mean post-test time increased by 17% to 85.5s. The core training group increased their mean time from 66.9 to 74.5 seconds. The control group improved from 77.7 to 86.8 seconds. Both the core and control groups improved by approximately 10%. Large standard deviations were observed in all three groups.

Table 3. Side Bridge

	Pre-Test		Post-Test	
Group	**Mean (seconds)**	**sd**	**Mean (seconds)**	**sd**
IMT	71.0	28.8	85.5	41.2
Core	66.9	21.7	74.5	21.5
Control	77.7	29.4	86.8	26.1

IMT=Inspiratory Muscle Training; Core=Core Training; sd=standard deviation

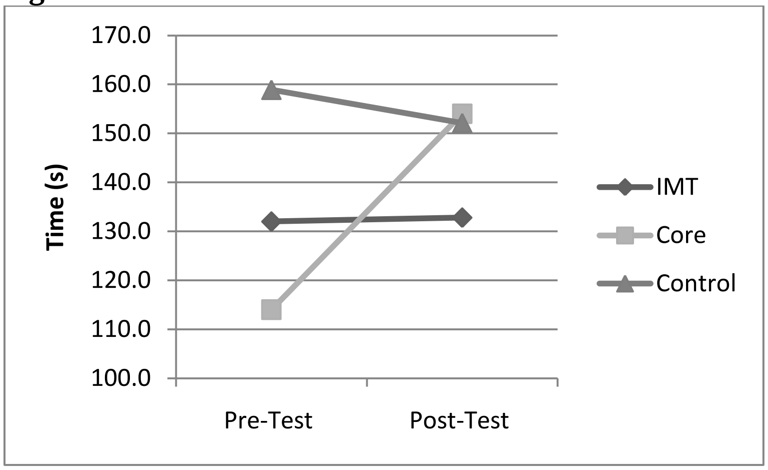
Prone Extension. A significant interaction was found for the prone extension test (F=4.983, p=0.014). A post hoc analysis indicated that the core training group improved significantly more than the other two groups (p=0.034). Table 4 and Figure 1 show the results for the prone extension endurance test. Pre-test mean time for the core group was 114.0 seconds and mean post-test time was 154.0 seconds. No significant change was found in the IMT or control group. The IMT group's mean pre-test time was 132.0 seconds and mean post-test time was 132.8 seconds. The control group's mean time decreased from 158.9 seconds to 152.1 seconds.

Table 4. Prone Extension

	Pre-Test		Post-Test	
Group	**Mean (seconds)**	**sd**	**Mean (seconds)**	**sd**
IMT	132.0	39.2	132.8	40.3
Core	114.0	53.0	154.0	77.6
Control	158.9	75.5	152.1	62.6

IMT=Inspiratory Muscle Training; Core=Core Training; sd=standard deviation

Figure 1. Prone Extension



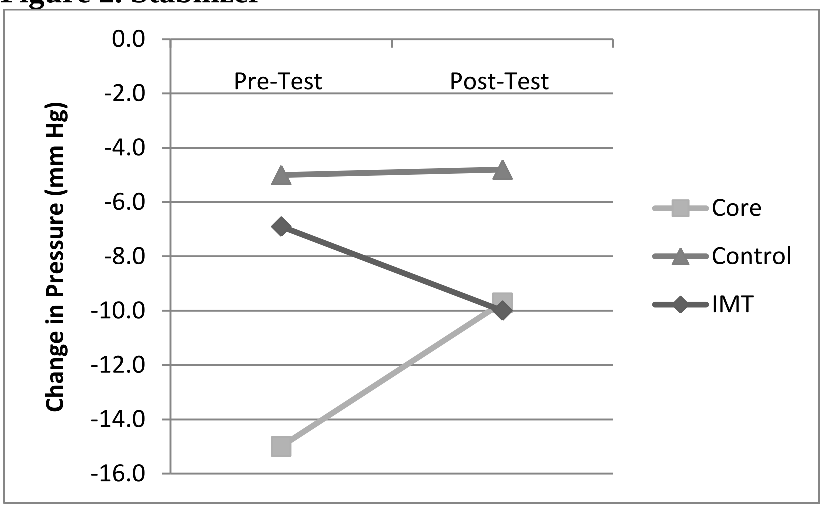
Stabilizer Pressure Change. There was a significant interaction for the Stabilizer test (F=3.678, p=0.038) as shown in Figure 2. Table 5 shows mean and standard deviations for each group. The mean score for the IMT group decreased from -6.9 to -10.0 mm Hg. This decrease indicates improved performance because contraction of the transversus abdominis lifts the abdomen up and away from the Stabilizer pad causing a decrease in pressure. One IMT subject was unable to perform the test correctly resulting in unusually high scores and was not included in the data analysis. During exhalation, most people perform a contraction of the transversus abdominis without the rectus abdominis (De Troyer, Estenne, Ninane, Van Gansbeke & Gorini**,** 1990). This subject most likely contracted the rectus abdominis during the test, creating a large increase in pressure. Scores for all other subjects ranged from -22 to 20 mm Hg. This subject scored 48 mm Hg during pre-testing and 52 mm Hg during post-testing. The core group increased the mean score from -15.0 to -9.7 mm Hg. The control group showed no change in performance, with a mean pre-test score of -5.0 mm Hg and a mean post-test score of -4.8 mm Hg. There was no significant difference between the three groups as baseline.

Table 5. Stabilizer

	Pre-Test		Post-Test	
Group	Mean (mm Hg)	sd	Mean (mm Hg)	sd
IMT	-6.9	12.6	-10.0	11.0
Core	-15.0	5.8	-9.7	10.4
Control	-5.0	12.1	-4.8	13.4

IMT=Inspiratory Muscle Training; Core=Core Training; mm Hg=millimeters mercury; sd=standard deviation

Figure 2. Stabilizer



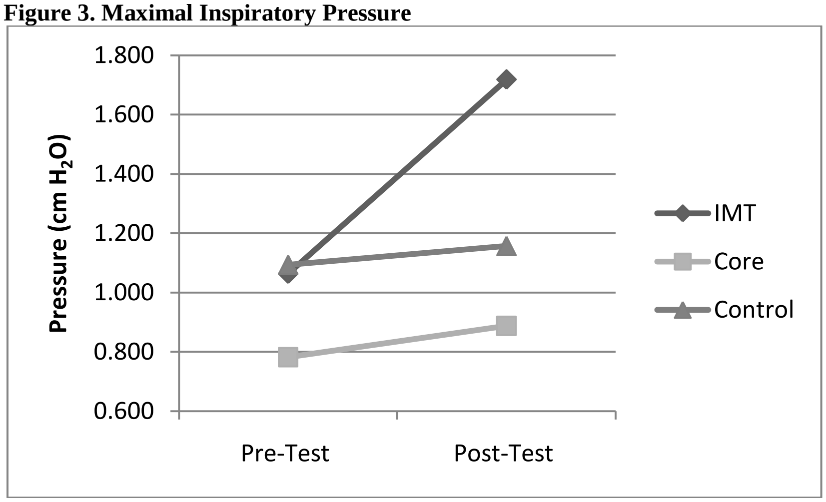
Maximal Inspiratory Pressure. A significant interaction for maximal inspiratory pressure (MIP) was found (F=30.068, p=0.000) as shown in Figure 3. Means and standard deviations are reported in Table 6. There was a significant increase in the mean score for the IMT group from 1.063 to 1.718 cm H_2O. The mean for the core training group increased from 0.782 to 0.887 cm H_2O, but the change was not significant. There was no significant change in the control group. Mean pre-test score was 1.093 cm H_2O and mean post-test score was 1.157 cm H_2O for the control group. Pre-test scores showed a significant difference between the core and control groups (p=0.034) on the test of MIP. There was no significant difference between the IMT and core or IMT and control groups before training.

Table 6. Maximal Inspiratory Pressure

	Pre-Test		Post-Test	
Group	Mean (cm H_2O)	sd	Mean (cm H_2O)	sd
IMT	1.063	0.372	1.718	0.418
Core	0.782	0.316	0.887	0.332
Control	1.093	0.290	1.157	0.367

IMT=Inspiratory Muscle Training; Core=Core Training; cm H_20=centimeters water; sd=standard deviation

Figure 3. Maximal Inspiratory Pressure



Discussion of Results

Tests of core function showed that both inspiratory muscle training and core training can both improve function of the core muscles. The null hypothesis, that there will be no difference in measures of core function between the core training group, inspiratory muscle training group, and control group, is rejected.

All three groups showed a significant improvement on the side bridge test. Although all subjects received the same instructions at the pre and post testing sessions, having performed the test previously may have had an effect on the effort during the post-test. The greatest improvement was observed in the inspiratory muscle training group. Inspiratory muscle training utilizes the diaphragm which contributes to intraabdominal pressure. An increase in strength of the diaphragm may contribute to an improved stabilization of the spine which is required in the side bridge test (Hodges, Eriksson, Shirley, & Gandevia, 2005). Subject effort may also have been a factor in this test. Subjects are asked to hold the position for as long as possible which may have been uncomfortable for some subjects.

The core training group was the only group to significantly improve performance on the prone extension test. The core training program targeted the extensor muscles in addition to the other muscles of the trunk. Similar improvements have been seen in other research on core training (Akuthorta, Ferreiro, Moore, & Fredericsson, 2008; Hides, Stanton, McMahon, Sims, & Richardson, 2008). Back extensor endurance can be improved through core training, but inspiratory muscle training did not have an effect on back extensor endurance on the prone extension test.

Improvements were observed in the IMT group over the core training group in the Stabilizer test of transversus abdominis contraction. An acceptable level of function is seen by a negative pressure difference of 6 or greater (Richardson et al., 2002). The mean score of the IMT group met this level at the post test. Transversus abdominis activity is increased with forced exhalation (Richardson et al., 2002). Although inspiratory muscle training focuses on inspiratory muscles, exhalation may also have been effected.

The core training group showed a rise in mean pressure difference indicating that core training had a detrimental effect on transversus abdominis contraction. Only one out of the 12 subjects improved after the six weeks of core training. A higher or more positive score may be a result of a contraction of other abdominal muscles, especially the rectus abdominis (Richardson et al., 2002). A correct contraction of the transversus abdominis may be accompanied by internal oblique contraction. The internal oblique contraction, however, would not impact the pressure change observed on the pressure biofeedback unit (Richardson et al., 2002). During the core training program, subjects would have been contracting the rectus abdominis while performing supine trunk flexion exercises (Hamill & Knutzen, 2003). This training may have contributed to the difference seen in the contraction in the core training group. These results are consistent with other research which examined the effects of abdominal curls and Pilates training on function of the transversus abdominis (Herrington & Davies, 2005). Seven out of the ten control subjects produced post-test scores within 4 mm Hg of their pre-test score and the mean score did not show a significant change.

Inspiratory muscle training significantly improved maximum inspiratory pressure (MIP), which is consistent with other research using similar training protocols (Gething, Passfield, & Davies, 2004; Riganas, Vrabas, Chistoulas, & Mandrokas, 2008; Williams et al., 2002). An improvement in fitness may also have contributed to an improvement in MIP (Al-Bilbeisi & McCool, 2000), but no change was observed in exercise or physical activity during the six week study.

Summary of Results

Six weeks of inspiratory muscle training showed an improvement in core muscle function. Function of the transversus abdominis improved in the IMT group. Side bridge endurance improved in all groups. Back extensor endurance was shown to improve with six weeks of core training. Specificity of training was an important predictor of performance on the tests of core muscle function. Improved performance on these core tests indicates that it is possible that IMT can be used to improve some aspects of core muscle function in healthy subjects.

Chapter V

Summary, Conclusions, and Recommendations

Summary

This study compared the effects of inspiratory muscle training and core training on core function when compared to a control group. Improvements were found in core function for both training groups. The IMT group improved maximal inspiratory pressure and their transversus abdominis function over the core training group. The core training group improved their back extensor endurance. Core training and inspiratory muscle training can both improve core function, but improve different muscles.

Conclusions

Inspiratory muscle training can improve the function of the transversus abdominis. The transversus abdominis is contracted during forced exhalation. This connection between the abdominal muscle and breathing may be used to train the core muscles using breathing techniques.

The core training program used in this study was effective at improving back extensor endurance. The core training seemed to have a detrimental effect on the subjects' ability to contract the transversus abdominis independent of the other abdominal muscles. The focus on strengthening the rectus abdominis seems to have had an effect performance on the Stabilizer test of transversus abdominis function.

Performance on the side bridge test improved in all groups including the controls who did not participate in any training. This indicates that this test may have a practice effect. Subject effort also impacts performance on the side bridge endurance test, as subjects choose to end the test when they can no longer maintain the position. Subject motivation may have affected the prone extension test similarly; however, the control group did not show any improvement on that test.

Inspiratory muscle training and core training impact the core muscles differently. Yoga and Pilates training include exercise for the core muscles as well as breathing practice. There is likely a benefit to utilizing a combination of these training programs to maximize results and improve core function.

Recommendations

The following recommendations are made for further research in this area:

1. Repeat this study with random assignment of subjects to inspiratory muscle training, core training, and control groups.
2. Repeat this study with a group which performs both inspiratory muscle training and core training to determine any further benefits of the combination of training programs. Core muscle exercise and breathing practice are often found in combination in yoga and Pilates.
3. Repeat this study with sedentary or unfit subjects.
4. Investigate the role of the transversus abdominis during inspiratory muscle training using fine wire electrodes or ultrasound to determine if and when contraction occurs while performing IMT.

Recommendations for application of findings. The results of this study can be used when designing core training programs. Inspiratory muscle training can have a positive effect on core muscle function and may be a beneficial addition to a traditional core training program. IMT could also be used to improve core function in those with physical limitations which prevent them from performing traditional core exercises.

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Appendix A

Informed Consent Form

Western Washington University
Department of Physical Education, Health, & Recreation
The Effects of Inspiratory Muscle Training or Core Training on Core Function

Informed Consent Statement

This study will be conducted to determine the effect of inspiratory muscle training (IMT) or core training on core function. The findings of this study will be used to determine the effectiveness of these training programs to improve core muscle function and respiratory muscle strength.

All participants in this study will report for a testing session prior to beginning training and following six weeks of either inspiratory muscle training (IMT), attending AbLab classes, or receiving no training. These testing sessions consists of four tests.

1. Maximal inspiratory pressure (MIP): participants will inhale into a device as forcefully as possible with the nose clipped shut.
2. Prone extension test: participants will lie face down on a table with the upper body unsupported and asked to hold the upper body in a straight position parallel to the floor for as long as possible.
3. Side bridge test: participants will support themselves on one hand and the side of the same foot with the body held in a straight position for as long as possible (this is also known as a side plank).
4. Transversus abdominis function: requires participants to lie on their stomach and contract the transverse abdominis by lifting the navel toward the spine without moving the spine or pelvis. A Stabilizer unit, which is similar to a blood pressure cuff, will be placed under the abdomen to measure changes in pressure.

Participants in the core training group will perform two 30-minute AbLab classes on days of their choice at the student recreation center. Participants in the IMT group will perform IMT once per day, each weekday for six weeks. IMT training sessions will last approximately 10 to 15 minutes each day. The control group will perform the two testing sessions only and will not receive any training. A survey of daily physical activity will be conducted before and after the study period to ensure no changes were made in physical activity levels for each group.

Potential benefits of participation in this study include increases in core muscle function and respiratory muscle strength. Improved core muscle function can reduce low back pain and improve athletic performance. Increases in respiratory muscle strength can decrease respiratory muscle fatigue, which may lead to improved exercise endurance.

Risks involved in this study are similar to those for most exercise programs. Muscle fatigue and soreness may occur for some participants. Every effort will be made to ensure safety, including instruction of proper form for all tests and exercises. The mouthpieces and noseclips used for the MIP test and Powerbreathe IMT trainers will be thoroughly cleaned after each use.

All research data will be kept confidential. A participant number will be assigned prior at the beginning of the study which will be used on all data sheets. Participant information will be kept in a locked cabinet and only used for the purposes of this study.

Participation in this study is voluntary and all participants are free to discontinue at any time.

Participants must be 18 years of age to participate in this study. Those with a history of low back pain or injury should not participate.

Any questions or concerns about participating in this study should be directed to Teresa Hahn at 253-228-9487 or hahnt2@students.wwu.edu or to Dr. Lorrie Brilla at 360-650-3056 or Lorrie.Brilla@wwu.edu. Any questions regarding your rights as a research subject may be directed to Geri Walker of the Human Subjects Review Committee at 360-650-3220 or Geri.Walker@wwu.edu. If any adverse effects result from participation in this study, please notify the researcher using the contact information above or the WWU Human Protections Administrator.

Once you have read and understand this informed consent statement, please sign and date below. You will be provided with a copy of this form.

Participant's Printed Name ____

Participant's Signature _____________________________________ Date _____________

Witness's Signature _______________________________________ Date _____________

Appendix B

Human Subjects Form

Human Subjects Activity Review Form

The Effects of Inspiratory Muscle Training or Core Training on Core Function

1. **What is your research question or specific hypothesis?** This study investigates the influence of inspiratory muscle training on core function compared to a typical core training program. It will determine if increased strength of the respiratory muscles shows similar improvements on tests of core strength and stability as a core training program.

2. **What are the potential benefits of the proposed research to the field?** This study provides information on how breathing, specifically inspiratory muscle training (IMT), can affect the function of core muscles. If similar results are found between IMT and core training, breathing exercise may be used as alternative or as a compliment to traditional training of core muscles.

3. **What are the potential benefits, if any, of the proposed research to the subjects?** Subjects participating in either of the two training groups, inspiratory muscle training or core training, may show improvements in core function as a result of the training. Improved inspiratory muscle strength will be a benefit for the inspiratory muscle training group.

4. **A. Describe how you will identify the subject population, and how you will contact key individuals who will allow you access to that subject population or database.** The population that will be used in this study consists of Western Washington University students. Subjects in the core training group will be participating in "AbLab" group fitness classes offered at the student recreation center during fall quarter 2009. The subjects will be a subset from the students who sign up for the class. Subjects in the inspiratory muscle training (IMT) and control groups will consist of volunteers from the university student body who were not currently participating in a core training program.
   B. Describe how you will recruit a sample from your subject population, including possible use of compensation, and the number of subjects to be recruited. The opportunity for inclusion in this research project will be presented when students purchase the pass for the class. Subjects for the IMT and control groups will be recruited using flyers posted at the student recreation center and Carver Gymnasium. Instructors of Kinesiology and 100 level Physical Education classes will be asked to announce the opportunity to participate in the study during their classes. All three groups, IMT, core training, and control, will consist of 20 subjects.

5. **Briefly describe the research methodology. Attach copies of all test instruments/questionnaires that will be used.** Subjects will be informed of the testing procedures and will complete an informed consent document. Tests of inspiratory muscle strength and core function will be performed before training begins. The same tests will be performed after six weeks of training. All tests used in this study have been previously conducted at Western Washington University. Maximal inspiratory pressure (MIP) will be measured using a device engineered at Western Washington University. This test requires subjects to perform a maximal inhalation against resistance. For the inspiratory muscle

training group, MIP will be measured at the beginning of each week of training for the IMT group and the IMT workload will set at 80% of each subject's MIP. Transversus abdominis function will be tested using a pressure biofeedback unit (Stabilizer, Chattanooga Group, Hixson, TX) which consists of an inflatable pad which measures change in pressure. Subjects will lie in the prone position with the unit beneath the abdomen and will be instructed to contract the tranversus abdominis by drawing the naval toward the spine without moving the spine or pelvis. A correct contraction will result in a negative pressure change. Tests of core function will also include a timed prone extension endurance test and side bridge endurance test. During the prone extension endurance test, the subject's lower extremities will be supported and the subject will hold the upper body in a position parallel to the floor. The body should remain straight with the neck in line with the spine. During the side bridge test, the subject will support their body on one hand and the same side foot with the spine in a straight, neutral position. Subjects will choose their preferred side for this test. Subjects will be timed while holding the position. Subjects in the IMT group will perform IMT training under supervision of the researcher. Five sets of 12 repetitions will be performed with a Powerbreathe (Southam, Warwickshire, UK) device each session. IMT will be performed once per day, Monday through Friday, for 6 weeks. Intensity will be set at 80% MIP and adjusted based on gains in MIP as training progresses. MIP will be tested at the beginning of each week to maintain training intensity at 80%. The core training group will participate in 30 minute group fitness classes twice per week for six weeks which focus on abdominal muscles. Typical exercises consist of various supine curl-ups, crunches, and stability ball exercises. The control group will not receive training as a part of this study. All subjects will submit a physical activity log and the beginning and end of the six weeks to ensure no changes are made in caloric expenditure.

6. **Give specific examples (with literature citations) for the use of your test instruments/questionnaires, or similar ones in previous similar studies in your field**. A test of maximal inspiratory pressure (MIP) is used to determine the strength of respiratory muscles (Johnson, Sharpe, & Brown, 2007, Lima, et al., 2008, Sanchez Riera, et al., 2001). Inspiratory muscle training (IMT) has been used with healthy and diseased individuals and improves strength and endurance of respiratory muscles (Downey, et al., 2007; Johnson, Sharpe, & Brown, 2007; Sanchez Riera, et al., 2001).
   The ability to properly recruit the transverse abdominis can be measured using a pressure biofeedback unit similar to that used for this study (Stanton, Raeburn, & Humphries, 2004). This test has been used for testing the effect of a Pilates program on transverse abdominis function (Herrington & Davies, 2005).
   Prone extension and side bridge tests are used to evaluate function of core musculature (Akuthota, et al., 2008). Training using these positions has been shown to improve performance on the test of transverse abdominis function (Stanton, et al., 2004).
   The Bouchard method will be used to estimate caloric expenditure. This requires a three-day log of physical activity (Bouchard, et al., 1983). Each 15-minute time period is assigned a rating of 1-9 based on the intensity of the activity. This method has been found to be a suitable way to estimate caloric expenditure in adults and children (Bouchard, et al., 1983).

7. **Describe how your study design is appropriate to examine your question or specific hypothesis. Include a description of controls used, if any.** The design is a three group study to assess core function. The three groups consist of an inspiratory muscle training group, core training group, and control group. Forty subjects will be selected from volunteers to the IMT and control groups. Supervised IMT will be performed Monday through Friday for six weeks. Five sets of 12 repetitions will be performed each day at 80% of maximal inspiratory pressure. Subjects perform IMT at approximately the same time of day for the duration of the training. Data will be excluded from subjects who miss more than three training sessions. Exclusion criteria was determined to ensure 90% adherence to training. Subjects (n=20) in the core training group will be selected from volunteers taking Ab Lab classes at the Wade King Student Recreation Center. Subjects in this group will be required to attend class twice per week during the duration of the study. Attendance will be recorded for each class. More than two absences from class excluded these subjects' data from the results. Exclusion criteria for this group was also determined to ensure 90% adherence. The control group will be instructed not to begin any new exercise program during the study. A kilocalorie expenditure analysis will be performed based on self-reported activity levels prior to and following the study to ensure subjects did not increase physical activity level. This requires subjects to record physical activity throughout the day on the Physical Activity Log. Tests of core function and maximal inspiratory pressure will be performed before and after the six week training period. Pre and post test data will be compared for these two training groups and the control group which received no training.

8. **Give specific examples (with literature citations) for the use of your study design, or similar ones, in previous similar studies in your field.** Inspiratory muscle training (IMT) programs show improvements in maximal inspiratory pressure in healthy adults when IMT is performed one time per day at a minimum of 50% maximal inspiratory pressure and four weeks of training (Downey, et al., 2007, Edwards, Wells, & Butterly, 2007, Johnson, Sharpe, & Brown, 2008, Nicks, Morgan, Fuller, & Caputo, 2009, Witt, Guenette, Rupert, McKenzie, & Sheel, 2007). This training program consists of 80% MIP and six weeks of training. Core training programs have been shown to effectively reduce low back pain and improve function of the transverse abdominis (Hides, et al., 2008). A Pilates program, consisting of breathing and abdominal muscle exercises also improved transverse abdominis function (Herrington & Davies, 2005).

9. **Describe the potential risks to the human subjects involved.** This research involves minimal risks to the participants. Muscle fatigue may result during testing as with any form of exercise. Noseclips and mouth pieces will be used for tests of maximal inspiratory pressure and during inspiratory muscle training.

10. **If the research involves potential risks, describe the safeguards that will be used to minimize such risks**. Correct form and performance of all core tests will be explained to subjects prior to testing. All noseclips and mouth pieces will be properly cleaned to avoid cross-contamination. After each use, these items will be rinsed with warm water and submerged into 10% a bleach solution then Alconox cleaner (a biodegradable soap) then

rinsed and dried. Subjects with a history of low back pain or injury will not be included in the study.

11. **Describe how you will address privacy and/or confidentiality.** Subjects in this study will be assigned numbers to ensure confidentiality. Research data will be stored in a locked cabinet in the Exercise Physiology Laboratory. Electronic data will be stored on an external device in the same locked cabinet.

12. This study does use the Western Washington University Wade King Student Recreation Center group fitness program to recruit and train subjects in the core training group. Attached is a clearance letter from Ron Arnold, the Fitness Coordinator for the Wade King Student Recreation Center.

Appendix C

AbLab Exercise Program

Although classes varied based on participants' abilities and experience, the following exercises are examples of those used during AbLab classes:

1. supine curl-ups
2. crunches
3. curl-up modifications such as a bicycle crunch or curl-up with trunk rotation
4. lying prone hip flexion exercises
5. stability ball exercises, including trunk flexion and extension
6. prone isometric extension exercises, also known as Superman
7. planks

Appendix D

Data Collection Sheets

IMT Data Collection Sheet

Subject Number: ____

Maximal Inspiratory Pressure

	Trial 1	Trial 2	Trial 3	Maximum
Week 1 - Pretest				
Week 2				
Week 3				
Week 4				
Week 5				
Week 6				

Powerbreathe Setting

Week 1	
Week 2	
Week 3	
Week 4	
Week 5	
Week 6	

Attendance

	Monday	Tuesday	Wednesday	Thursday	Friday
Week 1					
Week 2					
Week 3					
Week 4					
Week 5					
Week 6					

Pre-Test Data Collection Sheet

Subject Number: ____

Age: ____

Height: ____inches

Weight: ____pounds

Abdominal Circumference: ____ inches

Maximal Inspiratory Pressure (cm H_2O)

Trial 1	
Trial 2	
Trial 3	
Maximal	

Core Function

TrA test (change in pressure): ____

Trial 1	
Trial 2	
Trial 3	

Prone Back Extension: ____s

Side Bridge: ____s

Post-Test Data Collection Sheet

Subject Number: ____

Age: ____

Height: ____inches

Abdominal Circumference: ________ inches

Maximal Inspiratory Pressure (cm H_2O)

Trial 1	
Trial 2	
Trial 3	
Maximal	

Core Function

TrA test (change in pressure): ____

Trial 1	
Trial 2	
Trial 3	

Prone Back Extension: ______s

Side Bridge: _______s

Appendix E

Subject Characteristics

Group	Sub. Num.	Sex	Age	Height (in.)	Weight (lbs.) Pre	Post
IMT	1	M	25	74	171.5	167
	2	M	22	71.5	166	166
	3	F	20	68	141.5	136.5
	5	M	22	72.5	194	191.5
	6	F	20	69	179	177
	7	M	22	69	169	171
	11	M	21	75.5	204	194
	13	F	24	69	157.5	158.25
	14	F	20	65.5	163.5	169
	15	F	22	68.25	142	141
Core	21	F	20	63	113	111.5
	22	F	19	62.5	170.5	173.25
	23	F	23	64.5	136.5	139
	24	F	19	67.5	169	167.5
	25	F	22	62.5	118.5	112
	26	F	20	65	122	122.5
	27	F	18	65.2	138	144
	29	F	19	61.5	110.25	108.5
	30	F	18	65	146.5	151.5
	32	F	19	63.5	124.25	126.5
	33	F	19	66	127.5	128.5
	35	F	20	67	147	147.5
Control	42	F	20	66	131	132
	43	F	25	64.5	127	131
	45	F	23	66.5	129	127.5
	46	F	22	60	108	104
	48	F	22	66.5	150	146.5
	49	F	24	67	169	169
	50	M	22	65	135	139
	53	M	23	71.75	152	149
	54	F	22	65.5	128	129.5
	55	M	24	66.5	146.25	143

Appendix F

Subject Test Data

		MIP		Stabilizer		Prone Extension		Side Bridge		Diet		Energy Expenditure	
Group	Sub. Num.	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
IMT	1	0.980	1.784			108	108	95	143	2522.5	2018.7	3637.9	3585.4
	2	1.560	2.224	-12	-20	154	131	113	165	2375.6	2418.4	3608.7	3608.7
	3	0.464	0.796	10	-4	185	227	101	90	1614.7	1525.5	2624.2	2190.6
	5	1.300	2.180	16	16	114	128	91	97	2612.7	2626.4	2635.8	3230.5
	6	1.000	1.764	-14	-16	141	122	45	65	1548.2	1727.5	3240.4	2896.4
	7	0.860	1.656	-16	-20	206	166	38	32	2291.4	2209.2	3015.4	3518.5
	11	1.500	1.848	-22	-10	111	134	87	85	1996.5	1780.2	3808.0	3631.3
	13	1.040	1.318	-14	-12	109	134	43	68	1615.5	1880.2	3524.2	3119.0
	14	0.563	1.644	-2	-10	80	83	49	49	1217.9	1458.3	3281.9	3080.5
	15	1.368	1.968	-8	-14	112	95	48	61				
Core	21	0.720	0.728	-20	-8	186	170	106	120	1879.3	1816.5	2115.5	2137.1
	22	1.048	1.088	-16	-12	51	82	63	60	1650.8	1471.8	3269.5	3233.0
	23	0.356	0.524	-8	20			37	73	1922.3	1934.0	2804.5	2845.3
	24	0.408	0.664	-14	-8	64	102	64	87	1802.9	1193.2	3192.6	3258.1
	25	1.272	1.208	-18	-16	135	305	87	104	2596.5	2087.8	2895.2	2862.6
	26	1.116	1.348	-24	-18	148	244	71	71	977.0	1033.2	2587.1	2522.0
	27	0.996	1.188	-14	-12	82	98	42	47	1643.2	1750.0	2383.6	2530.9
	29	0.496	0.584	-12	-10	139	105	83	83	1814.5	1732.9	2119.8	2058.5
	30	0.520	0.428	-20	-12	65	88	39	53	2374.2	2468.7	2657.9	3108.3
	32	0.707	0.872	-20	-20	174	210	72	69	1975.2	2014.4	2317.8	2416.7
	33	0.612	0.668	-10	-16	70	99	52	54	2210.4	2433.3	2549.6	2426.3
	35	1.128	1.340	-4	-4	189	245	87	74	1901.6	1980.0	2834.4	2751.5
Control	42	1.000	0.956	-18	-16	167	142	109	114	1196.3	1243.2	1866.8	2491.2
	43	1.320	1.464	-12	-6	218	193	97	96	1201.2	1227.0	3755.0	2699.4
	45	0.504	0.552	-10	-16	176	154	80	84	1961.4	1362.1	3152.7	2904.9
	46	1.144	1.032	-20	-20	127	103	89	108	1514.5	1198.5	1866.8	1773.4
	48	0.780	0.868	4	0	141	181	85	108	2575.2	2162.7	3755.0	3621.2
	49	1.136	1.588	12	20	57	66	22	61	1826.1	1557.7	3117.8	3190.5
	50	1.180	0.972	14	16	178	178	32	26	1958.7	1822.5	2773.6	2502.0
	53	1.476	1.656	-10	-10	319	280	103	90	1695.4	1974.6	2870.5	2749.3
	54	1.004	0.984	2	-6	145	148	94	93	1688.5	1865.6	2485.5	2513.1
	55	1.388	1.496	-12	-10	61	76	66	88	1854.2	1860.4	3278.9	3225.7

Appendix G

ANOVA Results

General Linear Model

Within-Subjects Factors

Measure:MIP

test	Dependent Variable
1	pre
2	post

Between-Subjects Factors

		N
group	1	10
	2	12
	3	10

Descriptive Statistics

	group	Mean	Std. Deviation	N
pre	1	1.06350	.372464	10
	2	.78158	.315952	12
	3	1.09320	.290349	10
	Total	.96706	.348745	32
post	1	1.71820	.418298	10
	2	.88667	.331556	12
	3	1.15680	.367220	10
	Total	1.23094	.503187	32

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df
test	Pillai's Trace	.690	64.494[a]	1.000	29.000
	Wilks' Lambda	.310	64.494[a]	1.000	29.000
	Hotelling's Trace	2.224	64.494[a]	1.000	29.000
	Roy's Largest Root	2.224	64.494[a]	1.000	29.000
test * group	Pillai's Trace	.675	30.068[a]	2.000	29.000
	Wilks' Lambda	.325	30.068[a]	2.000	29.000
	Hotelling's Trace	2.074	30.068[a]	2.000	29.000
	Roy's Largest Root	2.074	30.068[a]	2.000	29.000

a. Exact statistic

b. Design: Intercept + group
Within Subjects Design: test

Multivariate Tests[b]

Effect		Sig.	Partial Eta Squared
test	Pillai's Trace	.000	.690
	Wilks' Lambda	.000	.690
	Hotelling's Trace	.000	.690
	Roy's Largest Root	.000	.690
test * group	Pillai's Trace	.000	.675
	Wilks' Lambda	.000	.675
	Hotelling's Trace	.000	.675
	Roy's Largest Root	.000	.675

Mauchly's Test of Sphericity[b]

Measure:MIP

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.
test	1.000	.000	0	.

Mauchly's Test of Sphericity[b]

Within Subjects Effect	Epsilon[a]		
	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
test	1.000	1.000	1.000

Tests of Within-Subjects Effects

Measure:MIP

Source		Type III Sum of Squares	df	Mean Square	F
test	Sphericity Assumed	1.196	1	1.196	64.494
	Greenhouse-Geisser	1.196	1.000	1.196	64.494
	Huynh-Feldt	1.196	1.000	1.196	64.494
	Lower-bound	1.196	1.000	1.196	64.494
test * group	Sphericity Assumed	1.116	2	.558	30.068
	Greenhouse-Geisser	1.116	2.000	.558	30.068
	Huynh-Feldt	1.116	2.000	.558	30.068
	Lower-bound	1.116	2.000	.558	30.068
Error(test)	Sphericity Assumed	.538	29	.019	
	Greenhouse-Geisser	.538	29.000	.019	
	Huynh-Feldt	.538	29.000	.019	

Tests of Within-Subjects Effects

Measure:MIP

Source		Type III Sum of Squares	df	Mean Square	F
test	Sphericity Assumed	1.196	1	1.196	64.494
	Greenhouse-Geisser	1.196	1.000	1.196	64.494
	Huynh-Feldt	1.196	1.000	1.196	64.494
	Lower-bound	1.196	1.000	1.196	64.494
test * group	Sphericity Assumed	1.116	2	.558	30.068
	Greenhouse-Geisser	1.116	2.000	.558	30.068
	Huynh-Feldt	1.116	2.000	.558	30.068
	Lower-bound	1.116	2.000	.558	30.068
Error(test)	Sphericity Assumed	.538	29	.019	
	Greenhouse-Geisser	.538	29.000	.019	
	Huynh-Feldt	.538	29.000	.019	
	Lower-bound	.538	29.000	.019	

Tests of Within-Subjects Effects

Measure:MIP

Source		Sig.	Partial Eta Squared
test	Sphericity Assumed	.000	.690
	Greenhouse-Geisser	.000	.690
	Huynh-Feldt	.000	.690
	Lower-bound	.000	.690
test * group	Sphericity Assumed	.000	.675
	Greenhouse-Geisser	.000	.675
	Huynh-Feldt	.000	.675
	Lower-bound	.000	.675

Tests of Within-Subjects Contrasts

Measure:MIP

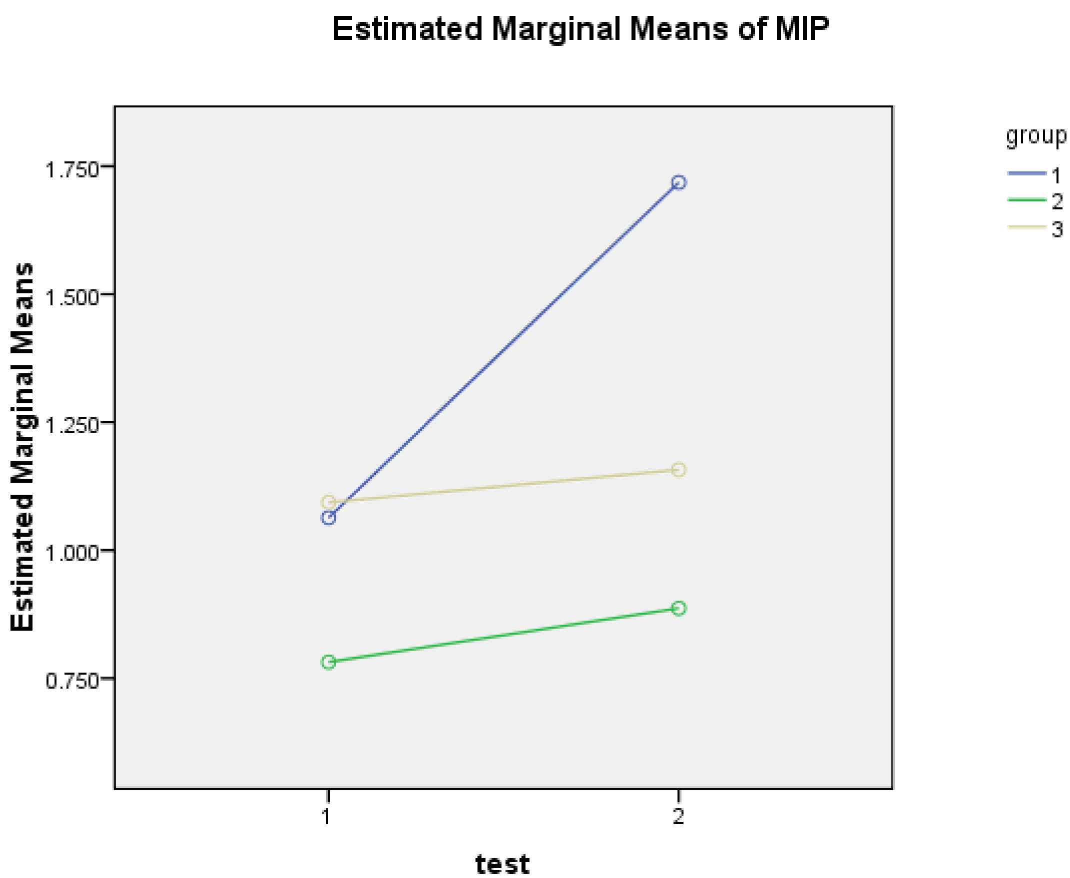
Source	test	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
test	Linear	1.196	1	1.196	64.494	.000	.690
test * group	Linear	1.116	2	.558	30.068	.000	.675
Error(test)	Linear	.538	29	.019			

Tests of Between-Subjects Effects

Measure:MIP
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	79.216	1	79.216	349.926	.000	.923
group	3.401	2	1.700	7.511	.002	.341
Error	6.565	29	.226			

Profile Plots



Stabilizer

General Linear Model

Within-Subjects Factors

Measure:stabilizer

test	Dependent Variable
1	Pre
2	Post

Between-Subjects Factors

		Value Label	N
Group	1.00	IMT	9
	2.00	Core Training	12
	3.00	Control	10

Descriptive Statistics

	Group	Mean	Std. Deviation	N
Pre	IMT	-6.8889	12.61393	9
	Core Training	-15.0000	5.81534	12
	Control	-5.0000	12.11977	10
	Total	-9.4194	10.94463	31
Post	IMT	-10.0000	11.00000	9
	Core Training	-9.6667	10.40396	12
	Control	-4.8000	13.37327	10
	Total	-8.1935	11.45839	31

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df
test	Pillai's Trace	.014	.383[a]	1.000	28.000
	Wilks' Lambda	.986	.383[a]	1.000	28.000
	Hotelling's Trace	.014	.383[a]	1.000	28.000
	Roy's Largest Root	.014	.383[a]	1.000	28.000
test * Group	Pillai's Trace	.208	3.678[a]	2.000	28.000

	Wilks' Lambda	.792	3.678[a]	2.000	28.000
	Hotelling's Trace	.263	3.678[a]	2.000	28.000
	Roy's Largest Root	.263	3.678[a]	2.000	28.000

Multivariate Tests[b]

Effect		Sig.	Partial Eta Squared
test	Pillai's Trace	.541	.014
	Wilks' Lambda	.541	.014
	Hotelling's Trace	.541	.014
	Roy's Largest Root	.541	.014
test * Group	Pillai's Trace	.038	.208
	Wilks' Lambda	.038	.208
	Hotelling's Trace	.038	.208
	Roy's Largest Root	.038	.208

b. Design: Intercept + Group
Within Subjects Design: test

Mauchly's Test of Sphericity[b]

Measure:stabilizer

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.
test	1.000	.000	0	.

Mauchly's Test of Sphericity[b]

Measure:stabilizer

Within Subjects Effect	Epsilon[a]		
	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
test	1.000	1.000	1.000

Tests of Within-Subjects Effects

Measure:stabilizer

Source		Type III Sum of Squares	df	Mean Square	F
test	Sphericity Assumed	9.963	1	9.963	.383
	Greenhouse-Geisser	9.963	1.000	9.963	.383
	Huynh-Feldt	9.963	1.000	9.963	.383
	Lower-bound	9.963	1.000	9.963	.383
test * Group	Sphericity Assumed	191.132	2	95.566	3.678
	Greenhouse-Geisser	191.132	2.000	95.566	3.678
	Huynh-Feldt	191.132	2.000	95.566	3.678
	Lower-bound	191.132	2.000	95.566	3.678

Error(test)	Sphericity Assumed	727.578	28	25.985	
	Greenhouse-Geisser	727.578	28.000	25.985	
	Huynh-Feldt	727.578	28.000	25.985	
	Lower-bound	727.578	28.000	25.985	

Tests of Within-Subjects Effects

Measure:stabilizer

Source		Sig.	Partial Eta Squared
test	Sphericity Assumed	.541	.014
	Greenhouse-Geisser	.541	.014
	Huynh-Feldt	.541	.014
	Lower-bound	.541	.014
test * Group	Sphericity Assumed	.038	.208
	Greenhouse-Geisser	.038	.208
	Huynh-Feldt	.038	.208
	Lower-bound	.038	.208

Tests of Within-Subjects Contrasts

Measure:stabilizer

Source	test	Type III Sum of Squares	df	Mean Square	F
test	Linear	9.963	1	9.963	.383
test * Group	Linear	191.132	2	95.566	3.678
Error(test)	Linear	727.578	28	25.985	

Tests of Within-Subjects Contrasts

Measure:stabilizer

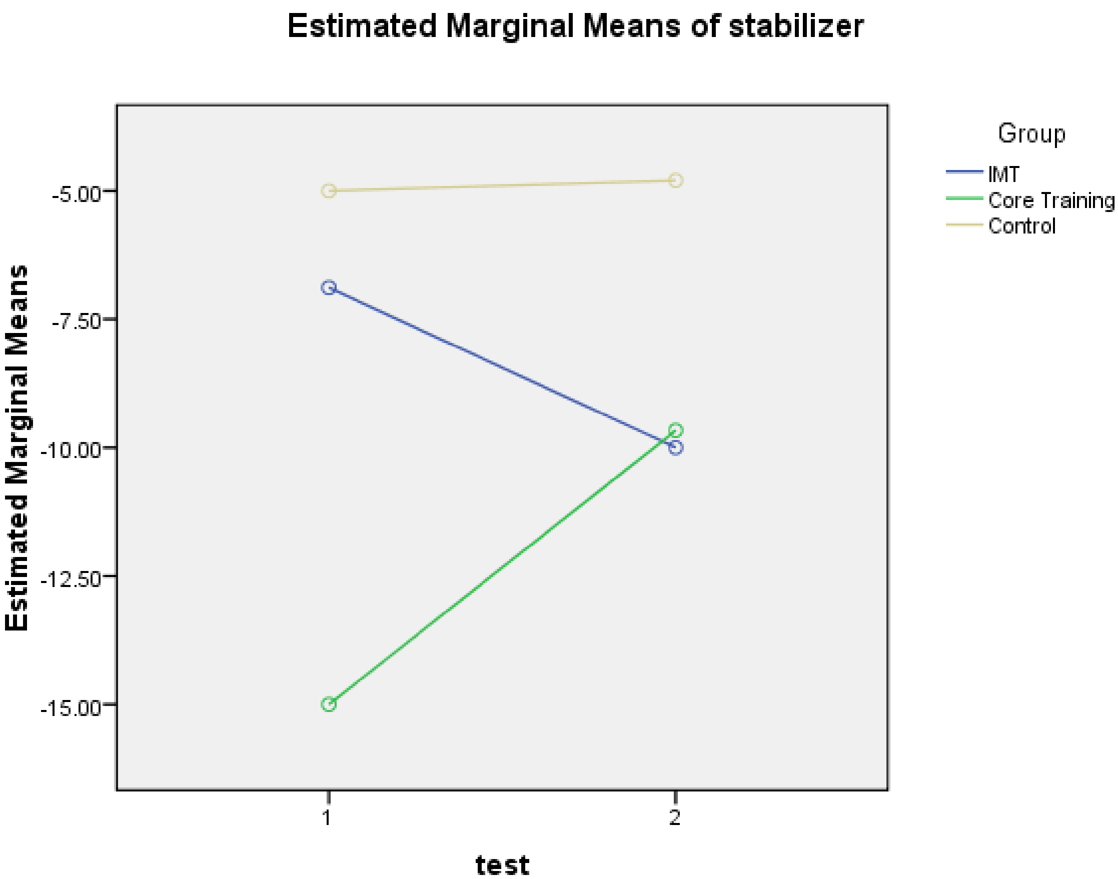
Source	test	Sig.	Partial Eta Squared
test	Linear	.541	.014
test * Group	Linear	.038	.208

Tests of Between-Subjects Effects

Measure:stabilizer
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	4478.592	1	4478.592	20.874	.000	.427
Group	606.100	2	303.050	1.412	.260	.092
Error	6007.578	28	214.556			

Profile Plots



Prone Extension

General Linear Model

Within-Subjects Factors

Measure:PExt

test	Dependent Variable
1	pre
2	post

Between-Subjects Factors

		N
group	1	10
	2	12
	3	10

Descriptive Statistics

	group	Mean	Std. Deviation	N
pre	1	132.00000	39.191836	10
	2	114.00000	52.968258	12
	3	158.90000	75.532848	10
	Total	133.65625	58.769429	32
post	1	132.80000	40.339669	10
	2	154.00000	77.633170	12
	3	152.10000	62.605378	10
	Total	146.78125	61.978006	32

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df
test	Pillai's Trace	.090	2.872[a]	1.000	29.000
	Wilks' Lambda	.910	2.872[a]	1.000	29.000
	Hotelling's Trace	.099	2.872[a]	1.000	29.000
	Roy's Largest Root	.099	2.872[a]	1.000	29.000
test * group	Pillai's Trace	.256	4.983[a]	2.000	29.000
	Wilks' Lambda	.744	4.983[a]	2.000	29.000
	Hotelling's Trace	.344	4.983[a]	2.000	29.000
	Roy's Largest Root	.344	4.983[a]	2.000	29.000

Multivariate Tests[b]

Effect		Sig.	Partial Eta Squared
test	Pillai's Trace	.101	.090
	Wilks' Lambda	.101	.090
	Hotelling's Trace	.101	.090
	Roy's Largest Root	.101	.090
test * group	Pillai's Trace	.014	.256
	Wilks' Lambda	.014	.256
	Hotelling's Trace	.014	.256
	Roy's Largest Root	.014	.256

Mauchly's Test of Sphericity[b]

Measure:PExt

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.
test	1.000	.000	0	.

Mauchly's Test of Sphericity[b]

Measure:PExt

Within Subjects Effect	Epsilon[a]		
	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
test	1.000	1.000	1.000

Tests of Within-Subjects Effects

Measure:PExt

Source		Type III Sum of Squares	df	Mean Square	F
test	Sphericity Assumed	2040.000	1	2040.000	2.872
	Greenhouse-Geisser	2040.000	1.000	2040.000	2.872
	Huynh-Feldt	2040.000	1.000	2040.000	2.872
	Lower-bound	2040.000	1.000	2040.000	2.872
test * group	Sphericity Assumed	7078.150	2	3539.075	4.983
	Greenhouse-Geisser	7078.150	2.000	3539.075	4.983
	Huynh-Feldt	7078.150	2.000	3539.075	4.983
	Lower-bound	7078.150	2.000	3539.075	4.983
Error(test)	Sphericity Assumed	20597.600	29	710.262	
	Greenhouse-Geisser	20597.600	29.000	710.262	
	Huynh-Feldt	20597.600	29.000	710.262	

Tests of Within-Subjects Effects

Measure:PExt

Source		Type III Sum of Squares	df	Mean Square	F
test	Sphericity Assumed	2040.000	1	2040.000	2.872
	Greenhouse-Geisser	2040.000	1.000	2040.000	2.872
	Huynh-Feldt	2040.000	1.000	2040.000	2.872
	Lower-bound	2040.000	1.000	2040.000	2.872
test * group	Sphericity Assumed	7078.150	2	3539.075	4.983
	Greenhouse-Geisser	7078.150	2.000	3539.075	4.983
	Huynh-Feldt	7078.150	2.000	3539.075	4.983
	Lower-bound	7078.150	2.000	3539.075	4.983
Error(test)	Sphericity Assumed	20597.600	29	710.262	
	Greenhouse-Geisser	20597.600	29.000	710.262	
	Huynh-Feldt	20597.600	29.000	710.262	
	Lower-bound	20597.600	29.000	710.262	

Tests of Within-Subjects Effects

Measure:PExt

Source		Sig.	Partial Eta Squared
test	Sphericity Assumed	.101	.090
	Greenhouse-Geisser	.101	.090
	Huynh-Feldt	.101	.090
	Lower-bound	.101	.090
test * group	Sphericity Assumed	.014	.256
	Greenhouse-Geisser	.014	.256
	Huynh-Feldt	.014	.256
	Lower-bound	.014	.256

Tests of Within-Subjects Contrasts

Measure:PExt

Source	test	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
test	Linear	2040.000	1	2040.000	2.872	.101	.090
test * group	Linear	7078.150	2	3539.075	4.983	.014	.256
Error(test)	Linear	20597.600	29	710.262			

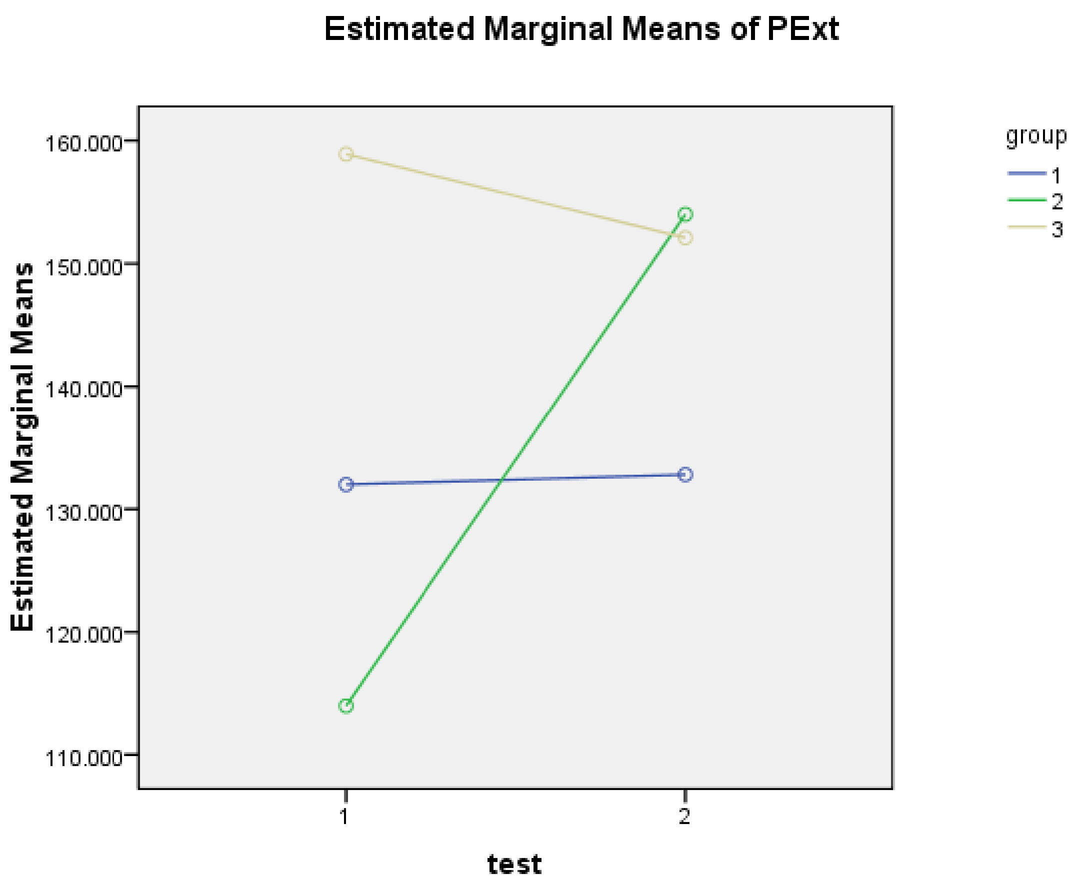
Tests of Between-Subjects Effects

Measure:PExt

Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	1256467.835	1	1256467.835	190.124	.000	.868
group	6821.138	2	3410.569	.516	.602	.034
Error	191651.800	29	6608.683			

Profile Plots



Side Bridge

General Linear Model

Within-Subjects Factors

Measure:SideBridge

test	Dependent Variable
1	Pre
2	Post

Between-Subjects Factors

		Value Label	N
Group	1.00	IMT	10
	2.00	Core Training	12
	3.00	Control	10

Descriptive Statistics

	Group	Mean	Std. Deviation	N
Pre	IMT	71.0000	28.78657	10
	Core Training	66.9167	21.69398	12
	Control	77.7000	29.38650	10
	Total	71.5625	26.05569	32
Post	IMT	85.5000	41.23173	10
	Core Training	74.5833	21.45379	12
	Control	86.8000	26.12704	10
	Total	81.8125	29.79439	32

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df
test	Pillai's Trace	.286	11.597[a]	1.000	29.000
	Wilks' Lambda	.714	11.597[a]	1.000	29.000
	Hotelling's Trace	.400	11.597[a]	1.000	29.000
	Roy's Largest Root	.400	11.597[a]	1.000	29.000
test * Group	Pillai's Trace	.031	.460[a]	2.000	29.000
	Wilks' Lambda	.969	.460[a]	2.000	29.000

	Hotelling's Trace	.032	.460[a]	2.000	29.000
	Roy's Largest Root	.032	.460[a]	2.000	29.000

Multivariate Tests[b]

Effect		Sig.	Partial Eta Squared
test	Pillai's Trace	.002	.286
	Wilks' Lambda	.002	.286
	Hotelling's Trace	.002	.286
	Roy's Largest Root	.002	.286
test * Group	Pillai's Trace	.636	.031
	Wilks' Lambda	.636	.031
	Hotelling's Trace	.636	.031
	Roy's Largest Root	.636	.031

Mauchly's Test of Sphericity[b]

Measure:SideBridge

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.
test	1.000	.000	0	.

Mauchly's Test of Sphericity[b]

Measure:SideBridge

Within Subjects Effect	Epsilon[a]		
	Greenhouse-Geisser	Huynh-Feldt	Lower-bound
test	1.000	1.000	1.000

Tests of Within-Subjects Effects

Measure:SideBridge

Source		Type III Sum of Squares	df	Mean Square	F
test	Sphericity Assumed	1725.184	1	1725.184	11.597
	Greenhouse-Geisser	1725.184	1.000	1725.184	11.597
	Huynh-Feldt	1725.184	1.000	1725.184	11.597
	Lower-bound	1725.184	1.000	1725.184	11.597
test * Group	Sphericity Assumed	136.967	2	68.483	.460
	Greenhouse-Geisser	136.967	2.000	68.483	.460
	Huynh-Feldt	136.967	2.000	68.483	.460
	Lower-bound	136.967	2.000	68.483	.460

Error(test)	Sphericity Assumed	4314.033	29	148.760	
	Greenhouse-Geisser	4314.033	29.000	148.760	
	Huynh-Feldt	4314.033	29.000	148.760	
	Lower-bound	4314.033	29.000	148.760	

Tests of Within-Subjects Effects

Measure:SideBridge

Source		Sig.	Partial Eta Squared
test	Sphericity Assumed	.002	.286
	Greenhouse-Geisser	.002	.286
	Huynh-Feldt	.002	.286
	Lower-bound	.002	.286
test * Group	Sphericity Assumed	.636	.031
	Greenhouse-Geisser	.636	.031
	Huynh-Feldt	.636	.031
	Lower-bound	.636	.031

Tests of Within-Subjects Contrasts

Measure:SideBridge

Source	test	Type III Sum of Squares	df	Mean Square	F
test	Linear	1725.184	1	1725.184	11.597
test * Group	Linear	136.967	2	68.483	.460
Error(test)	Linear	4314.033	29	148.760	

Tests of Within-Subjects Contrasts

Measure:SideBridge

Source	test	Sig.	Partial Eta Squared
test	Linear	.002	.286
test * Group	Linear	.636	.031

Tests of Between-Subjects Effects

Measure:SideBridge
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	377481.618	1	377481.618	256.971	.000	.899
Group	1513.750	2	756.875	.515	.603	.034
Error	42600.000	29	1468.966			

Profile Plots