ABSTRACT

Brilla LB, Kauffman TH. Effect of Inspiratory Muscle Training and Core Exercise Training on Core Functional Tests. JEPonline 2014;17(3):12-20. This study tested the effects of inspiratory muscle training on core function compared to a typical core training program. Subjects consisted of 32 healthy, recreationally active individuals (18-25 yrs of age) who were randomly assigned to one of three groups: Control (C), Inspiratory Muscle Training (IMT), and Core Exercise Class (AbEx). IMT performed inspiratory muscle training for 6 wks at 85% maximal inspiratory pressure (MIP), while AbEx performed standard core training of the same duration. Core function was assessed pre- and post-training using a side bridge, prone extension and Stabilizer test of transversus abdominis (TrA) function. MIP was also assessed before and after the treatment. Significant interaction effect was observed for MIP (P≤0.05). IMT MIP increased from 1.06 ± 0.37 to 1.71 ± 0.41 cm H2O (P≤0.05) with no significant pre-post changes in C (1.09 ± 0.29 to 1.15 ± 0.36 cm H2O) or AbEx (0.78 ± 0.31 to 0.88 ± 0.33 cm H2O). A significant interaction effect was noted in prone extension (P≤0.05). Time increased in AbEx from 114.0 ± 53.0 to 154.0 ± 77.6 sec (P≤0.05), with no significant changes in C (158.9 ± 75.5 to 152.1 ± 62.6 sec) or IMT (132.0 ± 39.2 to 132.8 ± 40.3 sec). A significant interaction for the Stabilizer test of TrA function was found (P≤0.05). The IMT group improved from -6.9 ± 12.6 to -10.0 ± 11.0 mmHg (P≤0.05), with no significant changes in the Control (-5.0 ± 12.1 to -4.8 ± 13.4 mmHg) or AbEx groups (-15.0 ± 5.8 to -9.7 ± 10.4 mmHg). There were no significant differences (P≥0.05) in the side bridge test. Six weeks of core training and inspiratory muscle training improve core function and target different muscles.

Key Words: Core Function, Inspiratory Muscle Training
INTRODUCTION

Strength training for the abdominal and lower back muscles is used for many purposes, including the improvement of 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 (14). Core training alone, however, has not been shown to have an impact on athletic performance (1). Core function also influences low back pain (8), and it has been shown that recruitment of core muscles is altered in people with low back pain (11). The transversus abdominis (TrA) muscles function as a key component of low back pain treatment and prevention (8,11) 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 (11). Training these recruitment patterns, especially the recruitment of the TrA, might help prevent low back pain (11).

Yoga and Pilates are popular forms of exercise. Both incorporate breathing with movements. Strength and stability gains observed in these programs may be related to the focus on breathing (7). A Pilates program improves a person’s ability to contract the TrA, which is an important skill for core strength and stability (7). The deep breathing used during yoga can increase core muscle activation and improve cardiorespiratory function (21).

Deep breathing exercises have been shown to require more abdominal muscle activity than abdominal crunches (16), 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 (5). Research has consistently shown that inspiratory muscle training improves respiratory muscle strength, but how this influences core stability is unknown (4,13,15,19). Alternatively, abdominal exercises, such as sit ups and leg lifts, compress the abdomen, leading to increased diaphragmatic work. The abdominal exercises yielded different pressures, some greater than 50% of the pressures generated during a maximal inspiratory maneuver (20). Some of these exercises generated high enough pressures to help strengthen the diaphragm.

Thus, the purpose of this study was to investigate the influence of inspiratory muscle training on core function compared to a typical core training program. It seeks to determine if increased strength of the respiratory muscles shows similar improvements on tests of core function and stability as a standard core exercise training program.

METHODS
Subjects
Thirty-two healthy, recreationally active subjects (18-25 yrs old) were randomly assigned to one of three groups: Control (C), Inspiratory Muscle Training (IMT), and Core Exercise Class (AbEx). All subjects were free of low back pain or injury. The IMT and Control subjects were not currently participating in a core training program. Data are reported for 10 IMT subjects (5 males, 5 females), 12 AbEx subjects (all females), and 10 Control subjects (3 males, 7 females). The subjects’ characteristics are presented in Table 1. All subjects read and signed an informed consent prior to data collection. This study was approved by the Human Subjects Review Committee.
Table 1. Description of the Subjects.

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (yrs)</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>BMI (kg·m⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMT</td>
<td>21.8 ± 1.7</td>
<td>78.1 ± 8.5</td>
<td>178 ± 7.8</td>
<td>24.0 ± 2.1</td>
</tr>
<tr>
<td>AbEx (Core)</td>
<td>19.7 ± 1.5</td>
<td>61.5 ± 9.8</td>
<td>164 ± 4.8</td>
<td>22.9 ± 3.1</td>
</tr>
<tr>
<td>Control</td>
<td>22.7 ± 1.4</td>
<td>62.5 ± 7.7</td>
<td>167 ± 7.3</td>
<td>22.2 ± 1.9</td>
</tr>
</tbody>
</table>

Mean ± SD for: IMT = Inspiratory Muscle Training; AbEx = Core Exercise Class; BMI = Body Mass Index

Procedures
A three group repeated measures design was used to study core function. Supervised IMT was 5 d·wk⁻¹ for 6 wks, 10 to 15 min totaling approximately 60 min·wk⁻¹. Data were excluded from the subjects who attended fewer than 90% of the training sessions. The subjects in the AbEx group were required to attend a 30-min class 2x·wk⁻¹ during the duration of the study. Less than 90% attendance to the classes excluded the subjects’ data from the results. The Control group received no training.

Data Collection
Tests of core function included a timed prone extension endurance test, side bridge endurance test, and a test of transversus abdominis (TrA) 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 while lying on an examining table. During the side bridge test, each subject supported their body on one hand and the same side foot with the spine in a straight, neutral position. Subjects chose their preferred side for this test. Maximal times for the endurance tests were recorded in seconds. Breaking from the correct position ended the test.

The test of TrA function measured the change in pressure during TrA contraction. The subjects began the test lying prone on a flat surface. The Stabilizer (Chattanooga Group, Hixson, TX), an inflatable pad, was positioned under the abdomen and inflated to 70 mmHg. The subjects were instructed to raise their abdomen away from the pad without appreciably moving the spine or pelvis and hold that position for 5 sec. Change in pressure was recorded from the Stabilizer unit. A negative change in pressure indicated contraction of the TrA. One practice test was performed, which was followed by three trials. The highest negative pressure value or lowest positive value of the three was used as the subject’s score.

Maximal inspiratory pressure (MIP) was measured using a device engineered at Western Washington University by Scientific Technical Services. The MIP was conducted during pre- and post-testing for the AbEx (core) training group and the Control group and weekly for the IMT group. Subjects performed the maneuver while standing. They were instructed to perform a maximal exhalation to residual volume, then, perform a maximal forced inhalation. The procedure was repeated two times allowing at least a 30-sec rest between each measurement. The highest value was recorded in cm H₂O.
The IMT subjects performed IMT under supervision. Five sets of 12 repetitions were performed with a Powerbreathe (Southam, Warwickshire, UK) device. IMT was performed 5 d·wk\(^{-1}\) for 6 wks. Intensity was set at 80% MIP, which 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 AbEx (core training) group participated in 30 min group fitness classes 2x·wk\(^{-1}\). The training focused on abdominal muscles for 6 wks. Typical exercises consisted of various supine curl-ups, crunches, and stability ball exercises. Although the Control group did not participate in any training, the subjects were tested at the same time the IMT and AbEx (core) subjects were tested.

### Statistical Analyses

A two-way mixed analysis of variance (ANOVA) was performed with the factors group and time (SPSS version 16). Group had three levels (IMT, AbEx, and Control). Time had two levels (pre- and post-intervention). If a significant change was found, post hoc analysis was performed. The alpha level was set at a probability of \(P \leq 0.05\).

### RESULTS

The data are reported for 10 IMT subjects (5 males, 5 females), 12 AbEx (core) subjects (all female), and 10 Control subjects (3 males, 7 females) as shown in Table 1. There were no differences in age, height, and 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.

The results for the AbEx (core) functional tests are presented in Table 2. On the side bridge test, there was no significant interaction. All three groups showed a significant increase in time on the side bridge test (\(P=0.002\)). The IMT group increased mean time by 17%, while the AbEx (core) and the Control groups improved ~10%. Large standard deviations were observed in all three groups.

### Table 2. Core Functional Tests (Mean ± SD).

<table>
<thead>
<tr>
<th></th>
<th>IMT (Pre-Test)</th>
<th>IMT (Post-Test)</th>
<th>AbEx (Core) (Pre-Test)</th>
<th>AbEx (Core) (Post-Test)</th>
<th>Control (Pre-Test)</th>
<th>Control (Post-Test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side Bridge (sec)</td>
<td>71.0 ± 28.8</td>
<td>85.5 ± 41.2</td>
<td>66.9 ± 21.7</td>
<td>74.5 ± 21.5</td>
<td>77.7 ± 29.4</td>
<td>86.8 ± 26.1</td>
</tr>
<tr>
<td>Prone Extension (sec)</td>
<td>132.0 ± 39.2</td>
<td>132.8 ± 40.3</td>
<td>114.0 ± 53.0</td>
<td>154.0 ± 77.6</td>
<td>158.9 ± 75.5</td>
<td>152.1 ± 62.6</td>
</tr>
<tr>
<td>Stabilizer (mmHg)</td>
<td>-6.9 ± 12.6</td>
<td>-10.0 ± 11.0</td>
<td>-15.0 ± 5.8</td>
<td>-9.7 ± 10.4</td>
<td>-5.0 ± 12.1</td>
<td>-4.8 ± 13.4</td>
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A significant interaction was found for the prone extension test (\(P=0.014\)). The post hoc analysis indicated that the AbEx (core) group improved significantly more than the IMT and Control groups (\(P=0.034\)). Figure 1 shows the results for the prone extension endurance test. No significant change was found in the IMT or Control group. Figure 2 shows there was a significant interaction...
for the Stabilizer test (P=0.038). The mean score for the IMT group decreased, which indicates improved performance because contraction of the transversus abdominis lifts the abdomen up and away from the Stabilizer pad causing a decrease in pressure. During exhalation, most people perform a contraction of the transversus abdominis without the rectus abdominis (3). The AbEx (core) group increased the mean score. The Control group showed no change in performance. There were no significant differences between the three groups at baseline.

Maximal inspiratory pressure (MIP) data are presented in Table 3. A significant interaction for MIP was found (P=0.000), as shown in Figure 3. There was a significant increase in the mean score for the IMT group. The mean increase in the AbEx (core) group and the Control group were not significant. Pre-test scores showed a significant difference between MIP for the AbEx (core) group and the Control group (P=0.034). No significant difference was found between the IMT group and the AbEx (core) or IMT and the Control group before training.

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre-Test (cm H₂O)</th>
<th>Post-Test (cm H₂O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMT</td>
<td>1.063 ± 0.372</td>
<td>1.718 ± 0.418</td>
</tr>
<tr>
<td>AbEx (Core)</td>
<td>0.782 ± 0.316</td>
<td>0.887 ± 0.332</td>
</tr>
<tr>
<td>Control</td>
<td>1.093 ± 0.290</td>
<td>1.157 ± 0.367</td>
</tr>
</tbody>
</table>

Mean ± SD for: IMT = Inspiratory Muscle Training; AbEx = Core Exercise Class; BMI = Body Mass Index

Table 3. Maximal Inspiratory Pressure.
DISCUSSION

Tests of core function showed that inspiratory muscle training (IMT) and core training (AbEx) improved the function of the core muscles. All three groups showed a significant improvement on the side bridge test. The greatest improvement was observed in the IMT group, which uses the diaphragm to contribute to intra-abdominal pressure. The increase in strength of the diaphragm may contribute to an improved stabilization of the spine that is required in the side bridge test (10). Additionally, the abdominal draw-in maneuver activates contraction of the transversus abdominis muscle (TrA). This action is similar to inspiring against a resistance. When the thickness of the TrA was measured by ultrasound to find the activation ratio, the TrA was activated in the side bridge test in both healthy and low back pain patients (9).

The AbEx (core) training group was the only group to significantly improve performance on the prone extension test. The training for the AbEx (core) program targeted the extensor muscles in addition to the other muscles of the trunk. Similar improvements have been seen in other research on AbEx (core) training (1,8). Back extensor endurance can be improved by core training, while IMT 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 TrA contraction. An acceptable level of function is seen by a negative pressure difference of 6 or greater (17). The mean score of the IMT group met this level at the post-test. Transversus abdominis activity is increased with forced exhalation (17). Although IMT focuses on inspiratory muscles, exhalation may also have been effected. A meta-analysis of respiratory muscle training confirmed better muscle endurance in muscles other than those targeted (12).

The AbEx (core) training group showed a rise in mean pressure difference indicating that core training had a detrimental effect on TrA contraction. Only one out of the 12 subjects improved after the 6 wks of core training. A higher or more positive score may be a result of a contraction of other abdominal muscles, especially the rectus abdominis (17). A correct contraction of the TrA may be accompanied by the contraction of the internal oblique muscles. However, contraction of these muscles would not impact the pressure change observed on the pressure biofeedback unit (17).

During the AbEx (core) training program, the subjects would have been contracting the rectus abdominis while performing supine trunk flexion exercises (6). This training may have contributed to the difference seen in the TrA contraction in the core training group. The results are consistent with other research that examined the effects of abdominal curls and Pilates training on function of the TrA (7). The control group was very consistent from baseline to post-test.

Inspiratory muscle training significantly improved maximum inspiratory pressure (MIP), which is consistent with other research using similar training protocols (5,18,22). An improvement in fitness may also have contributed to an improvement in MIP (2), but no change was observed in exercise or physical activity during the 6 wks of training.

Specificity of training was an important projection of performance on the tests of core muscle function. Six weeks of IMT showed an improvement in core muscle function by side bridge improvement, as has been implicated in other studies on non-respiratory muscle activation and influence on respiratory muscles such as the diaphragm (2,12). Function of the TrA improved in the IMT group. Back extensor endurance was shown to improve with 6 wks of core training. Improved performance on these core tests indicates it is possible that IMT can be used to improve some aspects of core muscle function in healthy subjects. However, it is important to remember that IMT
and AbEx (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 using a combination of these training programs to maximize results and improve core function.

CONCLUSIONS

The results of this study may be used when designing core training programs. Inspiratory muscle training can have a positive effect on core muscle function independent of specific core training. Thus, it may be a beneficial supplement to a traditional core training program. IMT may also be used to improve core function in subjects with physical limitations that prevent them from performing traditional core exercises.

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