DEVELOPMENT AND VALIDATION OF A CORE ENDURANCE INTERVENTION PROGRAM: IMPLICATIONS FOR PERFORMANCE IN COLLEGE-AGE ROWERS

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ABSTRACT. Tse, M.A., A.M. McManus, and R.S.W. Masters. Development and validation of a core endurance intervention program: Implications for performance in college-age rowers. J. Strength Cond. Res. 19(3):547±552. 2005.—The objective of this study was to examine the effectiveness of a core endurance exercise protocol. Forty-five college-age rowers (age 21 ± 1.0) were assigned to either a core training group (core group) (n = 25), which took part in a core endurance intervention exercise protocol, or to a control training group (control group) (n = 20), which was not given any specialized core training. Training took place 2 days per week for 8 weeks. Trunk endurance was assessed using flexion, extension, and side flexion tests, whereas a variety of functional performance measures were assessed (vertical jump, broad jump, shuttle run, 40-m sprint, overhead medicine ball throw, 2,000-m maximal rowing ergometer test). The results revealed significant improvement in the two side flexion tests for the core group (p < 0.05). Interestingly, significant differences were noted in the trunk extension test endurance times for the control group (p < 0.05), but not for the core group. No significant differences were found for any of the functional performance tests. In summary, the 8-week core endurance training program improved selected core endurance parameters in healthy young men, but the effectiveness of the core intervention on various functional performance aspects was not supported.

Key Words. trunk, torso endurance evaluation, core stability, multifidus, internal oblique

INTRODUCTION

Over the past decade core strength and core stability have been buzzwords in the sport and fitness industries. Despite an apparent lack of research investigating the effects of core strength/stability on sports performance, comments such as: "increasing core/trunk strength can lead to a greater capacity for speed generation, improved ability to change direction (agility), improved balance and posture, and decreased risk of injury" (8) are common. As a result of abundant media claims regarding the benefits of core stability and strength, there seems to be an increased emphasis on strengthening the muscles of the "core," i.e., the muscles of the trunk and pelvis, in addition to those muscles that connect the trunk to the legs, shoulders, and arms (16). Coaches have, through tradition, included some degree of torso training in their athletes' conditioning programs, because experience seems to have shown that training the trunk and pelvic musculature is beneficial (6, 10). Coaches of many sports like rugby, football, baseball, and tennis, among others, commonly tell their athletes that power is generated from the hips. Hodges and Richardson showed that transversus abdominis (TrA) activity precedes that of arm and leg movement by approximately 30 and 100 milliseconds, respectively, which may give some support to these intuitive claims by coaches and practitioners (11, 12). These findings imply that the TrA has a preparatory core stabilizing effect. Although the TrA is not a power-producing mobility muscle itself (7), it does assist in stabilizing the trunk, thus allowing power to be produced at the extremities.

Although research supporting the effects of core strength and stability on performance is sparse, considerable research on core stability and endurance has been carried out in the physiotherapy/rehabilitation field, with particular focus on spine pathology and the reduction of low back pain (LBP) by strengthening the core musculature. Some studies have implied that in addition to the effect on LBP, strong abdominal musculature may also be an important factor in enhancing athletic performance (5, 20, 33, 34), but again most of these claims are just assumptions. LBP in athletic populations is not uncommon and its occurrence has been well documented in various sports including football, golf, gymnastics, running, soccer, tennis, and volleyball (3, 4, 13, 14, 19, 25–27, 31, 35). Although core strength exercises are often introduced into an athlete's or patient's exercise program in an attempt to prevent LBP, contrary to what is commonly thought, evidence suggests that trunk muscle endurance, not strength, is related to reduced symptoms (2).

The core musculature includes muscles of the trunk and pelvis that are responsible for maintaining the stability of the spine and pelvis and are critical for the transfer of energy from larger torso to the smaller extremities during many sport activities. The body's stabilization system has to function optimally to effectively utilize strength, power, endurance, and neuromuscular control. If the extremity muscles are strong and the core is weak, a sufficient summation of forces cannot be created to perform efficient movements.

Theoretically, core strength and stability training will lead to greater maximal power and thus more efficient use of the muscles of the shoulders, arms, and legs; better body balance; and a lower risk of injury. Although there are still many questions that need to be answered regarding the effects of increased core endurance/stability on helping to prevent LBP, the evidence leans toward core endurance and stability having positive benefits for reducing LBP (2, 17). The main purpose of this study was to examine the effectiveness of a core training program on improving core endurance, and as a secondary interest, to determine if changes in core endurance, although
proven to be beneficial in reducing and preventing LBP, also have any additional effects on various aspects of performance, such as speed, power, agility, and aerobic endurance.

**METHODS**

**Experimental Approach to the Problem**

This study involved a two-factor experiment to address whether a core endurance intervention protocol improved core musculature endurance, and whether these changes had any effects on various functional performance tasks. Factor one was test, which had two levels: pre- and post-testing. Factor two was training, which also had two levels: core or control group. Dependent variables included various measurements of trunk muscle endurance, as well as a variety of performance tests for speed, power, agility, and aerobic endurance.

**Subjects**

Forty-five subjects with an average of 1 year of rowing experience were recruited from local university rowing clubs. In the month prior to the study, the subjects typically participated in 3–5 rowing sessions per week and were not undergoing a formal resistance training routine at the time. It should be noted that university rowers in Hong Kong are only seasonal athletes and not elite-level rowers. All subjects gave written informed consent in accordance with the ethical guidelines of the University of Hong Kong. All subjects were preparing for an interuniversity rowing competition at the end of the summer and therefore preferred to train with their own teams. Teams were subsequently assigned to a core training group (core group) consisting of 25 subjects who received specialized trunk training or a control training group (control group) consisting of 20 subjects who did not receive any core training instruction, but because they were also training for a rowing competition, did include some basic, traditional trunk exercises in their circuit program two times per week (bent-knee sit-ups 3 × 30 reps, back extension, right and left side flexion on back extension apparatus 3 × 20 reps each).

Eleven subjects withdrew from the study: two in the final phase because of injury, three after initial testing, two due to incompletion of testing, and five due to lack of sufficient attendance during the intervention period. Therefore, 34 subjects completed all requirements of the study (core group = 20; control group = 14).

**Core Training Protocol**

The core group subjects trained twice per week over an 8-week period, completing 14–16 training sessions. Each trunk session lasted approximately 30–40 minutes and started with a warm-up protocol that included spinal mobility exercises and stretches, such as the cat/camel, a back arching exercise done while on the hands and knees to increase mobility and blood flow to the spinal region.

The initial few sessions of the core endurance protocol started with trunk muscle stability exercises. Subjects were taught how to effectively activate the TrA and multifidus muscles, which have been shown to be important muscles for stabilizing the trunk (28, 29), in both the prone and seated positions. Air pressure cuffs and four-point stance abdominal wall raising techniques were used to teach TrA activation (30). When they were able to activate these muscles the subjects were then progressed to postural and stability exercises for approximately 2 weeks. Thereafter, exercises were introduced as the weeks progressed, going on to static–dynamic exercises and then to controlled mobility exercises. From weeks 4–8 these types of exercises were maintained, as more strenuous core endurance exercises were introduced. In addition to doing a specialized core training program, the core group also performed the same general circuit training program as that done by the control group, which included one exercise for each major muscle group for 2 cycles of between 12–15 reps per exercise at a moderate intensity only of approximately 50% repetition maximum.

**Testing Procedures**

Trunk muscle endurance was measured in a physiotherapy laboratory with the same clinician performing all measurements. All participants were instructed on how to carry out each test and were allowed two familiarization trials before actual testing. Physical performance testing took place at least 48 hours after trunk muscle endurance tests. The sequence of performance tests was vertical jump, standing broad jump, 10-m shuttle run, 40-m sprint, 2-kg medicine ball overhead throw, and 2,000-m indoor rowing ergometer. The vertical jump, standing broad jump, and medicine ball overhead throw were each recorded as the best of 3 trials. Subjects were allowed at least 30 seconds between each attempt. The 10-m shuttle run and 40-m sprint were both recorded as the best of 2 trials, allowing at least 5 minutes of recovery between each trial. A minimum of 5 minutes of rest was also provided between each of the different performance tests, and 30 minutes of rest before commencement of the 2,000-m indoor rowing test. At the end of the 2,000-m test, time, maximum heart rate, and lactate values were measured as markers of maximal effort. Before all testing or exercise training sessions, subjects performed 5–10 minutes of warm-up activities, consisting of various dynamic stretching and mobility exercises.

**Core Endurance/ Stability Tests**

McGill identified a number of tests as valid and reliable for showing torso muscular endurance. The four tests, extensor test (back extensor test), flexor test (abdominal fatigue test), and side bridge tests were shown to have reliability coefficients of between 0.97 and 0.99 (21, 22).

The back extensor test used (see Figure 1) was the Biering-Sorensen test (2), which has also been shown to be consistently reliable as a measure of low back extensor endurance. The upper body was cantilevered out over a test bench with the lower legs secured. The arms were folded across the chest with hands held on opposite shoulders. The test was terminated when the subject fell below the horizontal position.

The abdominal fatigue test (see Figure 2) was performed by having the subject sit on a bench with a back support that was at an angle of 60°. Both the knees and hips were flexed at 90° and the feet were fixed securely to the bench with a canvas strap and towel over bare feet to protect against chafing.

The arms were folded across the chest with the hands placed on opposite shoulders. Subjects leaned against a 4-inch-thick rubber pad that was wedged between their back and the 60° back rest. Subjects were instructed to maintain their body position once the supporting wedge
was removed to initiate the test. The test ended when the upper body could no longer be maintained at a 60° angle.

Because of the laboratory setting the side bridge (lateral musculature endurance) test (see Figure 3) was performed with the subject on top of a 2-inch-thick foam-padded massage table lying on either side with legs extended. The top foot was placed in front of the lower foot for added support. Subjects were instructed to support themselves on only the elbow, forearm, and feet. The hips were raised off the table surface and a straight body position was maintained in the frontal plane. The non-supporting arm was held across the chest with hand placed on the opposite shoulder. The test was terminated when the hips began to sag and body position could not be maintained, or when the lower leg started to rest on the massage tabletop.

During each of the tests the subjects were reminded that these were maximum effort tests and that they should maintain each position for as long as possible. Only the subject and evaluator were present in the testing room. Subjects were given no feedback about the duration of their tests or their final scores.

**Performance Tests**

The performance tests consisted of a number of common field tests for power, speed, agility, and a rowing-specific test for aerobic power. The tests included vertical jump, standing broad jump, 10-m shuttle run, 40-m sprint, 2-kg overhead medicine ball throw, and a 2,000-m maximal rowing ergometer test.

Vertical jump is a test for lower-body power. Testing was done using the Vertec® vertical jump tester, allowing both countermovement and arm swing.

Standing broad jump is commonly used as a test for horizontal jumping power. This traditional field test was done on a firm, plastic mat, which was $3 \times 1$ m in dimension, with markings at every 5 cm.

Shuttle run is commonly used as a test to show agility, but reliability coefficients have been reported between 0.46 and 0.94 (15, 18). The subjects ran 10 m to pick up a bean bag and sprinted back to the start line to place down the first bag before sprinting back for the second bag and then turning and sprinting past the timing device. The time was measured with the Speedtrap® electronic timing device.

The 40-m sprint measures running speed. This test was also timed using the Speedtrap electronic timing device.

Medicine ball throw is a test for upper-body throwing power without use of rotational throwing torque. A 2-kg medicine ball was thrown from the overhead position as far as possible. The subjects were permitted to quickly extend the body and hyperflex the arms at the shoulders in the sagittal plane before rapidly flexing the torso and throwing as far as possible.

After a 30-minute rest the 2,000-m rowing ergometer test was carried out under controlled temperature of 26–27° C. The time to complete 2,000 m, as well as measure maximum heart rate and final lactate, were also recorded as markers of maximal effort.

**Statistical Analyses**

Descriptive data are expressed as means and standard deviations. A $2 \times 2$ (test × training) analysis of variance with repeated measures was used to test for main effects of test, training, and the interaction between these fac-
Table 1. Pretraining physical characteristics of the core and control groups (mean ± SD).

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Age (y)</th>
<th>Height (m)</th>
<th>Weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core</td>
<td>20</td>
<td>21 ± 1.0</td>
<td>1.74 ± 0.04</td>
<td>68.4 ± 8.6</td>
</tr>
<tr>
<td>Control</td>
<td>14</td>
<td>20.1 ± 1.0</td>
<td>1.75 ± 0.06</td>
<td>67.3 ± 5.8</td>
</tr>
</tbody>
</table>

Figure 4. Mean right side bridge values pre- and postintervention.

Figure 5. Mean left side bridge values pre- and postintervention.

Figure 6. Mean back extensor test values pre- and postintervention.

Results

Physical characteristics (see Table 1) for each group did not differ significantly (p > 0.05) at the commencement of the study. Heights remained unchanged and stable body weight was also reported.

Core Endurance Tests

Abdominal Fatigue Test. There were no significant differences (p > 0.05) between the core group (n = 18) and control group (n = 14) for the abdominal fatigue test, where mean values (s) were 206.9 ± 92.1 (pre), 215.5 ± 62.7 (post) and 164.5 ± 7.2 (pre), 176.2 ± 48.9 (post) for core and control groups, respectively.

Right Side Bridge. Although no significant between-group differences were evident for right side bridge (p > 0.05), a main effect of test was found [F(1,30) = 24.1; p < 0.005], along with an interaction [F(1,30) = 24.1; p < 0.005]. As is clear from Figure 4, the interaction can be explained by increases in right side bridge strength of the core group only.

Left Side Bridge. No significant differences were evident between the core and control groups for left side bridge (p > 0.05). However, a main effect of test was present [F(1,30) = 27.1; p < 0.005], with an interaction [F(1,30) = 13.6; p < 0.001]. Again, it is evident that the core group shows a greater increase in left side bridge endurance than the control group (see Figure 5).

Back Extensor Test. No main effect of group was evident for the back extensor test (p > 0.05); but there was a main effect for test [F(1,29) = 10.3; p < 0.05] and an interaction [F(1,29) = 12.5; p < 0.001]. This can be explained by the increase in control group only (see Figure 6).

Physical Performance Tests. Table 2 shows the pre- and post-test means (±SD) for the physical performance tests for the core and control groups. The number of rowing training hours for core and control groups were marginally different and therefore we accounted for these differences by using number of hours of rowing training as a covariate. No significant between-group or within-group differences (p > 0.05) for any of the physical performance tests were found. Likewise, no interactions were shown for any of these measures.

Rowing Ergometer Test (2,000 m). Table 3 shows the pre- and post-test means (±SD) for the 2,000-m ergometer test for both core and control groups. In both groups a similarly high heart rate and lactate value were recorded in pre- and post-tests, indicating that maximal efforts were attained on both occasions. Pre- and post-test means (±SD) are also shown in Table 3 for these two markers of intensity. Again, as with the physical performance tests, there were no significant differences either between or within the two groups, and no interaction (p > 0.05).
**TABLE 3.** 2000-m rowing ergometer test after 8 weeks of training intervention or nonintervention period (mean ± SD).

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Baseline (pretest)</th>
<th>8 Wk (post-test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2kMRET (s)*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>16</td>
<td>454.5 ± 11.5</td>
<td>452.4 ± 9.8</td>
</tr>
<tr>
<td>Control</td>
<td>13</td>
<td>443.5 ± 10.5</td>
<td>442.1 ± 9.5</td>
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<tr>
<td>MaxHR (bpm)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>16</td>
<td>187.8 ± 8.7</td>
<td>189.6 ± 8.5</td>
</tr>
<tr>
<td>Control</td>
<td>13</td>
<td>196.9 ± 15.9</td>
<td>192 ± 7.1</td>
</tr>
<tr>
<td>MaxLA (mmol·l⁻¹)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core</td>
<td>16</td>
<td>12.2 ± 1.9</td>
<td>12.9 ± 2.5</td>
</tr>
<tr>
<td>Control</td>
<td>13</td>
<td>12.1 ± 2.6</td>
<td>12.7 ± 2.3</td>
</tr>
</tbody>
</table>

* 2kmMRET = 2 kilometer maximal rowing ergometer test; MaxHR (bpm) = maximal heart rate in beats per minute; MaxLA (mmol·l⁻¹) = maximal lactate in millimoles per liter of blood.

**DISCUSSION**

The primary focus of the research was to investigate the effectiveness of a core endurance intervention on improving the endurance of the trunk muscles. The results showed significant improvements in both right and left side bridge tests for the group undertaking the core intervention program. The results also showed no significant changes in the abdominal fatigue test for either the core or control training groups. The minimal improvement in either the core or control groups may have been due to the already high test scores in our subjects in comparison to endurance times for these tests as shown by McGill, Childs, and Liebenson (22), where a mean time of 144 ± 70 seconds for abdominal fatigue test in a group of 31 young healthy men was demonstrated. However, in that study (22), ratios for the other three tests were normalized to back extensor test because this test showed the longest hold times. In this research study the back extensor test values were not the highest, which led us to believe that the rowers in our study may have had unusually high conditioning of the abdominal flexor musculature. It should be noted that methodological procedure is also very important when carrying out the abdominal fatigue test. We observed that while the back was kept at a 60° position, even slight protraction and rounding of the shoulder blades or minimal flexion of the neck created an obvious reduction in loading on the flexor musculature. This should be taken into consideration when comparing data across studies.

One particularly unexpected finding was the significant improvement ($p < 0.05$) in back extensor test for the control training group but not the core group. Although the core and control groups did display marked differences in pretest back extensor test values of 136.5 ± 36.2 and 100.5 ± 20.7 respectively, the magnitude of the between-group difference was not significant. Despite the difference not being statistically significant, the substantial improvement in back extensor test for the control group may have been a result of the initial pretest scores being much lower than those of the core group, which one might not really expect to see in such a homogeneous group of university rowers, with similar mean heights, weights, ages, level of conditioning, and rowing experience. Another possible factor that may have led to an improvement in the control group and not the core group is motivation. Field tests of this nature have been shown to be heavily influenced by motivation (1). Some of the subjects in the core group may have been less motivated to carry out the posttest to maximal effort because of less-than-desired results in their team rowing competition. The core group may not have been motivated to push themselves to a new maximum level, whereas the control group, which may have been underperforming in the pretest, were able to reach similar back extensor test values to those of the core group in the posttest.

The trunk-training intervention in this study was quite short in duration and concentrated primarily on core stability and then endurance. The focus of the first few weeks was to teach the participants how to properly contract and utilize the TrA muscle. One possible reason for the significant improvements in right and left side bridges, but not in abdominal fatigue or back extensor tests for the core group, is that the muscles of the trunk flexors and extensors are used quite often in the rowing movement, which primarily takes place in the sagittal plane. The improvement in posttest right and left side bridge scores may have been due to the introduction of lateral flexion exercises in the intervention—movements that are not specifically carried out in the normal rowing stroke.

An alternative explanation for lack of improvement in the trunk flexor or extensor tests for the core group is that the training intervention also stressed dynamic endurance exercises in the final 4–5 weeks. Morrissey, Harmon, and Johnson showed that each kind of training produces the greatest improvement when strength tests used are similar to those of training (24). Most improvements are observed when the test routine matches the training routine. In this experiment there was little static training, whereas the four trunk endurance tests were static and isometric in nature.

In the second part of our study we tried to determine whether our core endurance intervention protocol had any effect on markers of performance. There were no significant pre- to post-test changes for any of the physical performance tests or the rowing ergometer test. This may have been due to a number of factors. First, the intervention program that we carried out did not yield the improvements in core endurance that we had expected. It could have been that the intervention program was too short to elicit a significant effect. We chose 16 workouts over 8 weeks because these college-level rowers were not highly trained athletes and we felt that this was an acceptable minimum for producing a significant change. In particular, since the subjects started a new core training intervention with initial emphasis on muscle activation and progressive strengthening, we expected that time would have been sufficient for strength improvements because of altered neural responses (9, 23, 32). It is also possible that there may have been significant changes in the performance tests pre and post, but that our methods of testing were not refined enough to pick up small changes. It is also possible that although endurance of the core stability muscles has been shown to have positive effects on reducing LBP, it may actually be strength and power of the trunk muscles that have an influence on physical performance tasks.

We are also aware that the margins for improvement were relatively small in this well-conditioned group. In the future it might be more prudent to work with non-competitive, healthy individuals and to use alternative techniques for assessing function of the core musculature.
such as electromyogram or isokinetic testing. In this study we focused on core endurance and to some degree core stability. However, further research is required to investigate whether core strength, endurance, or stability, or all three, have significant influences on aspects of performance and function.

PRACTICAL APPLICATIONS
In this study, those taking part in the core intervention program showed some significant changes in areas of the trunk musculature. Despite the fitness industry being rampant with claims that developments in trunk strength and stability are strongly linked to improving athletic performance, to our knowledge, there are no studies comparing strengthening of the core musculature and its effects on physical performance parameters such as power, speed, agility, and muscular endurance.

Although this study has still not been conclusive in identifying a relationship between training of the core and improvements in physical performance tasks, it would appear that the type of short-term preseason core training program used in this study could be beneficial by yielding improvements in core endurance, and thus training program used in this study could be beneficial and reducing episodes of LBP.

REFERENCES

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