

# Core Muscle Strengthening on a Portable Abdominal Machine

Jerrold S. Petrofsky, PhD\*

Maria Cuneo, DPT\*

Russell Dial, DPT\*

Amy Morris, DPT†

Ashley K. Pawley\*

Jennifer J. Hill, BST†

\*Department of Physical Therapy, Loma Linda University, Loma Linda, California

†Department of Physical Therapy, Azusa Pacific University, Azusa, California

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## ABSTRACT

Twenty-nine men and women who were between 17 and 49 years of age were examined to evaluate the effectiveness of a new abdominal exercise device, the Cross Crunch machine (Savvier, LP, Carlsbad, CA), on muscle use during abdominal flexion exercises. Subjects were a mixture of fit and sedentary individuals. They were engaged in exercise on the Cross Crunch machine in the seated position, and the exercise was compared with supine conventional crunches without the machine. The muscles studied were the rectus abdominis and the external oblique muscles.

To evaluate the use of the muscles, electromyogram (EMG) electrodes were placed on the right and left rectus abdominis muscles and the right and left external oblique muscles. The relationship between workload on the portable abdominal machine and EMG of the rectus abdominis and oblique muscles was linear. At the heaviest workload, work accomplished (duration x EMG amplitude) with the Cross Crunch was 1.9 times higher than the work per-

formed in an abdominal crunch for the rectus abdominis muscles and 4.4 times higher for the oblique muscles with the abdominal machine compared with abdominal crunches. These differences were significant ( $P < 0.01$ ). Thus, the Cross Crunch machine provided a reliable form of exercise for the abdominal and oblique muscles with one simple movement and can be performed in the seated position.

## INTRODUCTION

It is well established that abdominal and lower back strength is important in preventing lower back and soft-tissue injuries during lifting tasks.<sup>1,2</sup> For example, Iwai et al<sup>3</sup> showed that muscle strength was directly related to disability level and lower back pain in young individuals such as collegiate wrestlers. While the same relationship does not seem to hold for young children,<sup>4</sup> in young and older adults, paraspinal and abdominal muscle dysfunction first leads to abnormal muscle activity during exercise<sup>5</sup> and later to reduced muscle strength and eventual back injuries.<sup>6,7</sup>

Certainly, lower back strength and abdominal strength are not the only factors that contribute to lower back

**Table 1.** General Characteristics of Subjects

	<b>Age (years)</b>	<b>Weight (kg)</b>	<b>Height (cm)</b>
<b>Mean ± SD</b>	38.3 ± 13.4	73.3 ± 15.3	167.3 ± 11.8

injury. In a recent publication, back extensor strength in smokers was less than in nonsmokers with the same level of lower back pain.<sup>8</sup> Even in well-trained athletes such as gymnasts, low back pain can be a limiting factor in their lives.<sup>9</sup> In addition, abdominal exercise can be important in rehabilitation for improving bowel and bladder function.<sup>10</sup>

Once lower back pain and injuries occur, it is tempting to use surgical intervention such as lumbar fusion to resolve chronic pain.<sup>11</sup> Surgery is also often performed for curvature of the spine, even in young soldiers with back pain.<sup>12</sup> But surgical techniques are often very painful, costly, with poor prognosis, and the results are no different than what can be seen in good therapeutic exercise programs.<sup>13</sup> However, even if surgery has been performed, proper lower back and abdominal strengthening is important in the rehabilitation after surgery.<sup>14</sup>

Perhaps one reason why athletes develop a high proportion of lower back pain is that many types of athletic training do not train muscles evenly on both sides of the abdominal area and across the lower back. For example, when muscle fatigue and fatigue-related biochemical changes were assessed during cyclic lifting tasks, imbalances existed across the spinal cord causing a torque at the disk if one side of the body was fatigued more than the other.<sup>15,16</sup> This association between muscle fatigue and lower back injury or pain has been observed by multiple investigators.<sup>16,17</sup>

The most common abdominal exercise is a partial curl. The exercise can be performed supine with the feet on the floor and 12" to 18" apart, with the knees

flexed.<sup>18</sup> Abdominals are flexed to lift the shoulders and head off the floor to an angle of 30°. The arms may be crossed at the chest or the level of the head with the fingers next to the ears. A partial curl is considered the closest to the ideal position to maximize the use of the abdominal muscles.<sup>19</sup> Another position is with the knees flexed to 90° with the feet on the wall, this will emphasize the rectus abdominis muscles.<sup>20</sup> Cat stretches can also be used for the lower back muscles, and a variety of exercise techniques are used for the oblique muscles.

In an effort to exercise the abdominal muscles, many machines have been developed for use in athletic training<sup>21</sup> and after abdominal surgery.<sup>22</sup> Abdominal exercise can also be performed in the seated position by a variety of different machines.<sup>21,23</sup> But whether an abdominal exercise is done on a machine, in a seated position, or on the floor, there is variation in muscle activity.<sup>19,24</sup> Substitution of other muscles is common and hinders training of the abdominal and lower back muscles.<sup>25</sup> Ultimately, back extensor and abdominal strength are still considered the gold standard for analyzing a predisposition to back injuries.<sup>26-29</sup> As such, it is important to understand which muscles are used and to what extent the exercise is accomplishing these goals. This analysis of muscle use can be performed with the surface electromyogram (EMG).<sup>30</sup>

The EMG, when measured by surface electrodes above an active muscle, represents an interference pattern that provides the summation of activity of the underlying muscle fibers.<sup>31</sup> The amplitude of the surface EMG is gener-



**Figure 1.** Exercise device used in these studies.

ally related to the tension developed in muscle.<sup>31,32</sup> Therefore, the EMG provides a useful measure in assessing both the extent of muscle activity and muscle fatigue.<sup>33-36</sup> There is a linear relationship between the amplitude of EMG and tension in muscle during brief contractions.<sup>31,33,37</sup> However, the absolute amplitude of the EMG varies from day to day. Variation has been attributed to the type of electrode (needle or surface) or the size or position of the electrodes.<sup>38,39</sup> However, the EMG provides an accurate and reliable index of muscle use if it is normalized in terms of the maximum EMG during a maximum muscle contraction on a given day.

Recently we observed considerable muscle training and balance training bilaterally across the abdominal muscles with a small portable exercise device

called the 6 Second Abs machine (Savvier, LP, Carlsbad, CA).<sup>19,24,40</sup> This study describes the evaluation of a different machine called the Cross Crunch (Savvier, LP) which is somewhat similar in function to the 6 Second Abs machine in that resistance is provided through latex bands; however, the Cross Crunch is more compact and is specifically designed to perform a side torso twisting crunch that is performed in the seated position. This is particularly important for people who are overweight or older and, due to deconditioning, would find it impossible to exercise on the floor. Seated exercises could encourage activity in this population.

## **SUBJECTS**

Twenty-nine subjects (14 men, 15 women) participated in these experiments. This population was chosen based on power analysis of the variance to provide reliability in the analysis. Their ages ranged between 17 to 49 years old. The general characteristics of the subjects are shown in Table 1. All experimental protocols and procedures were approved by the Human Review Committee at Azusa Pacific University, and all subjects signed a statement of informed consent acknowledging that they are fully aware of the purposes and procedures of the project.

## **METHODS**

### **Exercise Device**

The exercise machine was a commercial exercise device that was produced by Savvier, LP, of Carlsbad, California (Figure 1). The device consisted of a rectangular plastic frame with an elastic band on the inside to adjust resistance. Resistance could be increased in 3 different stages so that it became increasingly more difficult to compress the rectangle (30, 50, or 75 lbs) (13.6, 22.7, or 34 kg). The upper part of the rectangle was placed in the subject's hands with



**Figure 2.** Strength measurement during the study for oblique muscles.

the base of the machine on the seat to the left or right of the subject (Figure 1). The device was then compressed fully, thereby exercising the oblique muscles.

### **EMG**

The EMG was recorded through 2 bipolar vinyl adhesive electrodes (silver, silver-chloride) with an active surface area of 0.5 cm<sup>2</sup>. One electrode was placed over the belly of the active muscle. The second electrode was placed 2 cm distal to the active electrode. EMG was amplified using a 4-channel amplifier, whose frequency response was flat from DC to 1000 Hz. The common mode rejection ratio of the amplifier was greater than 120 dB. The EMG was then digitized at 1000 samples/second by a Biopac 16-bit analog to digital converter (Biopac Inc., Santa Barbara, CA) and displayed and



**Figure 3.** Oblique side-bending exercise.

stored on a computer for later analysis. The amplitude of EMG was assessed by digitizing and half wave rectifying the raw data and calculating the mean voltage of rectified EMG.

### **Measurement of Strength of the Abdominal Muscles**

Isometric strength of the abdominal muscles was measured in the seated position. To accomplish this, subjects sat with the hips at an angle of 90°. A modified exercise device with strain gauges was used to assess maximum strength. Strength was measured in the forward, left, and right rotation directions (Figure 2). The strain gauge was linear from 0 to 200 kg of force. The output of the trans-

**Table 2.** Strength of the Subjects

	Flexion	Right Rotation	Left Rotation
Strength (kg)			
Mean ± SD	65.8 ± 12.5	48.5 ± 8.0	43.9 ± 9.1

**Table 3.** Variability in Resistance of Exercise Device to Fully Depress the Machine (kg) by Band Color

Trial	Band Color		
	Yellow	Orange	Red
1	14.5	18.3	42.1
2	15.8	27.6	32.3
3	22.4	26.2	34.4
4	19.8	23.8	41.6
Mean ± SD	18.1 ± 3.6	24.0 ± 4.1	37.6 ± 5.0

ducer was amplified with a strain gauge conditioner amplifier with a gain of 1000 and digitized in a Biopac 16-bit analog to digital converter and displayed and stored on a computer. The output was stored and analyzed as the average strength over the middle of a 3-second contraction. Strength was measured by an isometric contraction for 3 seconds. At least 1 minute was allowed between each of 3 contractions to allow for recovery.

### Procedures

First, EMG was assessed during a maximum effort as well as strength during flexion facing forward and while the trunk was rotated to the left and right as described in the Methods section. Next, EMG was assessed over the left and right rectus abdominis and left and right external oblique muscles during the following exercises:

The abdominal machine was placed on the side of the subject with the base on the chair. The arms were placed on the handles so the body of the subject was rotated to the left to perform the oblique side-bending exercise (Figure 3). The machine was depressed fully over a 2- to 3-second period. The arms were

then reversed to the right-hand side and the exercise repeated.

A standard crunch was performed while laying supine on the floor with the hip and knees bent to approximately 45° and the arms folded and crossed over the chest. No device was used and the subject lifted his or her shoulders high enough for his or her scapulae to clear the floor.

Finally, for 4 sets of resistive bands, the force to depress the bands in the machine was tested to verify the tension and linearity of the machines.

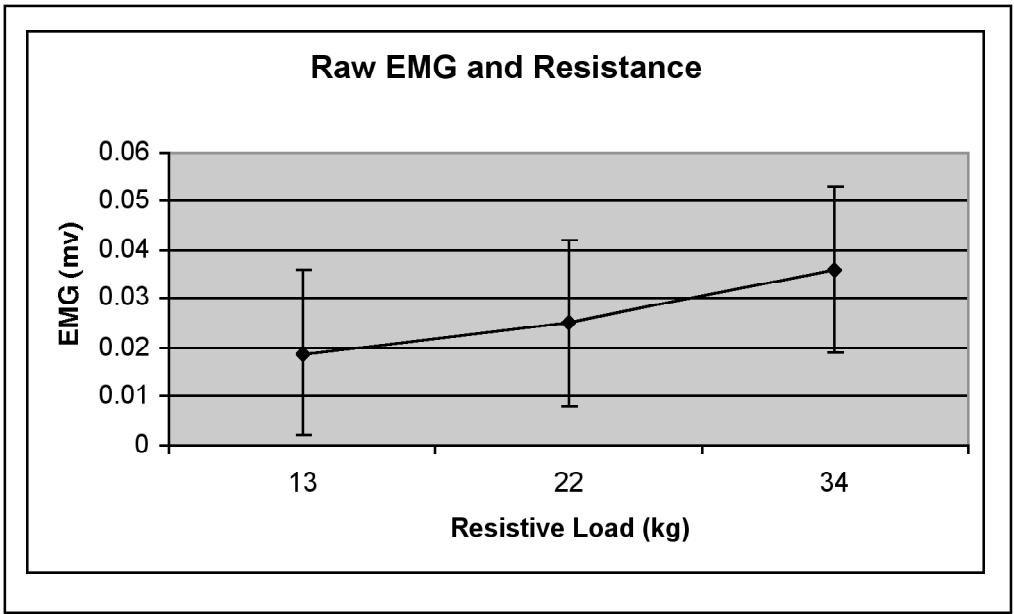
Each exercise was performed over a 3-minute period while EMG was measured. All exercises were repeated in part 1 at 3 loads (30, 50, and 75 lbs or 13.6, 22.7, and 34 kg).

### Data Analysis

Statistical analysis involved the calculations of mean standard deviations, analysis of variance (ANOVA), and *t*-tests. The level of significance was  $P < 0.05$ . EMG was analyzed over 3-second periods through the digitized EMG data.

### RESULTS

Muscle strength during flexion of the abdominal muscles in the forward facing



**Figure 4.** The relationship between load and EMG activity (raw EMG) for the group of subjects  $\pm$  the SD for left bending abdominal exercise. The muscle shown is the left oblique muscle.

direction and during right and left rotation exercises is shown in Table 2. Table 2 displays the mean  $\pm$  the respective standard deviation for the group of subjects. Muscle strength was greatest for flexion and lowest for the right and left rotations.

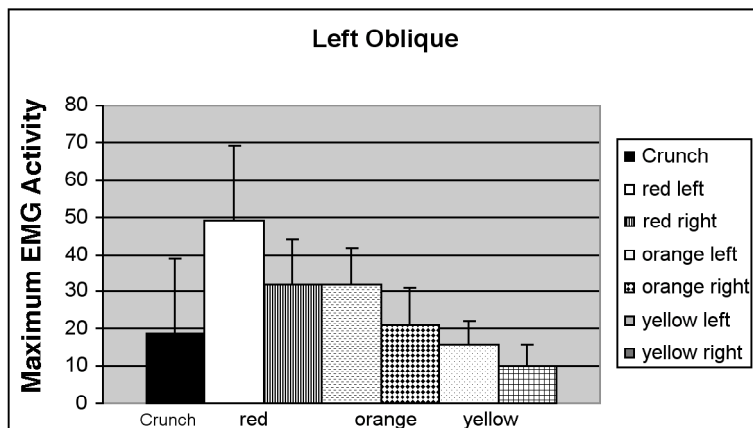
The force necessary to compress the abdominal exercise machine fully against the 4 different sets of resistance bands that were tested is shown in Table 3.

The average force to depress the Cross Crunch machine to the fullest extent for the 3 colors of resistance bands was 18.1, 24.0, and 37.6 kg. This corresponded to a load of 39, 52, and 82 lbs for the 3 bands. For the group of subjects as a whole, the maximum resistance of the device was less than the maximum strength of the subjects, but for some subjects, the maximum resistance of the device did exceed the maximum strength of the subjects. The average strength of the men for right rotation, for example, was 51.1 kg, a force more

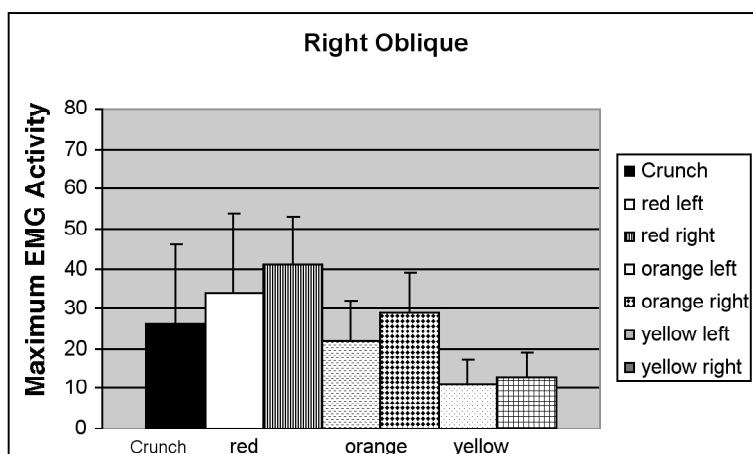
than adequate to depress the machine fully, whereas for the women, maximum strength was 35.6 kg, making it impossible for some women to fully depress the machine. However, the data from these women were averaged in the results to the fullest extent that they could depress the machine.

The EMG activity during flexion of the abdominal muscles with use of the abdominal machine was linearly related to the workload. For example as shown in Figure 4, for facing left, as the resistance was increased by changing the bands, so did the EMG activity of the muscles. But the variation from one subject to the next was large as shown by the large standard deviations in this figure. Therefore, EMG, rather than being expressed as an absolute value, was normalized in the remainder of the analysis as a percent of the maximum muscle activity during the maximum strength determinations. This allowed for differences in EMG activity between one individual and another.

A



B

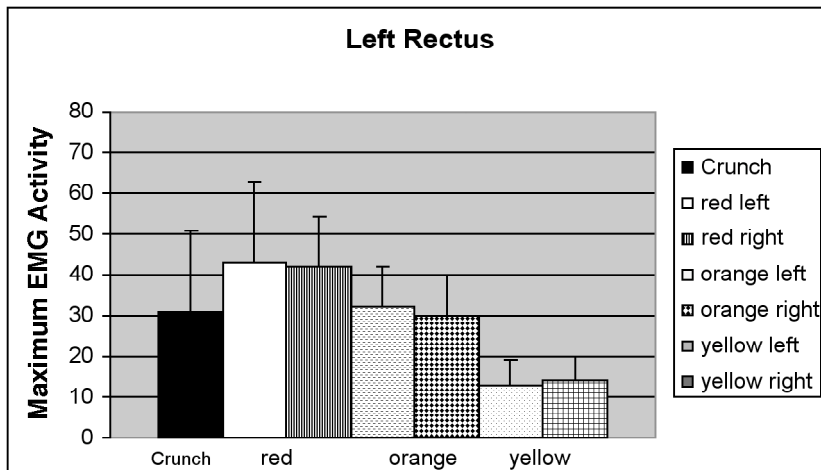


**Figure 5.** Illustrated here is the average muscle activity of the left and right oblique and left and right rectus abdominis muscles during each of the three exercises. Each panel shows EMG activity expressed as a percentage of the EMG during the maximum strength determinations. Data from the (A) left oblique muscles, (B) the right oblique muscles, (C) left rectus abdominis muscles, and (D) the right rectus abdominis muscles. The three exercises are left and right abdominal exercises in the seated position compared with standard abdominal crunches lying supine on the floor. All data are the mean result for the entire group  $\pm$  the respective SD. Data are shown for the yellow, orange, and red bands for the left and right muscle groups (left and right bars).

The average normalized muscle activity in the left oblique, right oblique, left rectus abdominis, and right rectus abdominis are shown in Figure 5 during exercise. Each panel shows muscle activ-

ity from one of the four muscles during left and right side-bending exercise and standard abdominal crunches. The greatest muscle activity was during exercise against the red band. Here, as shown in

C



D

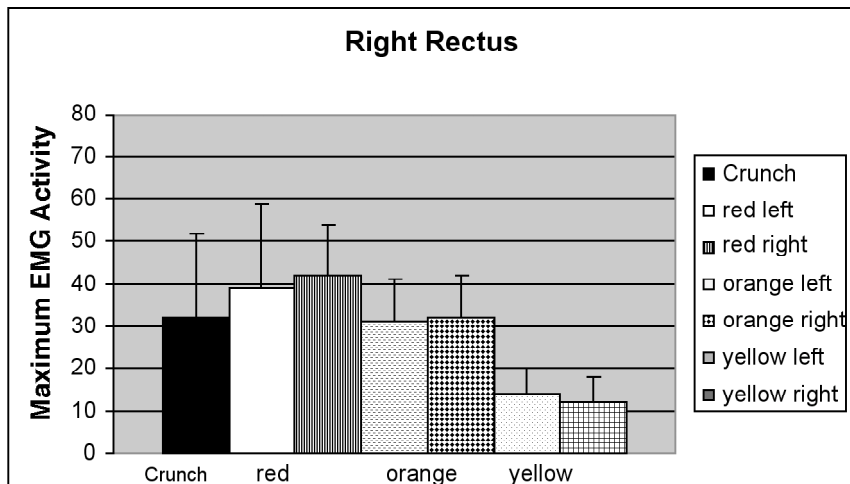


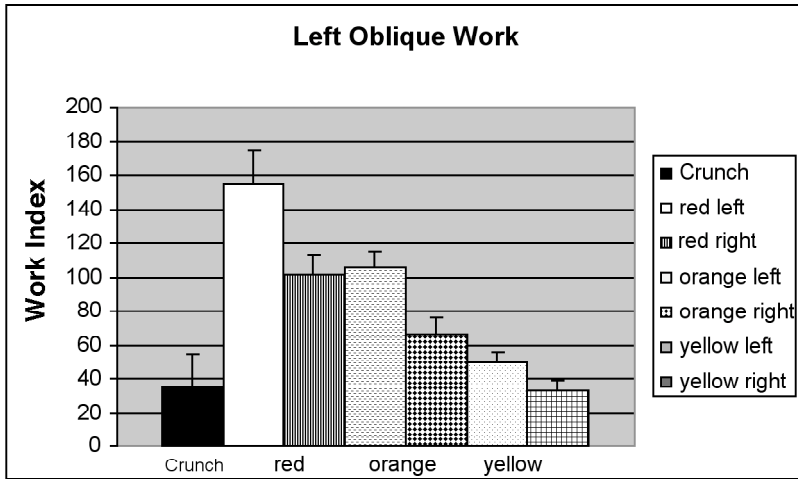
Figure 5, muscle activity was still one third higher for the rectus abdominis than that seen for standard crunches. For the red band, the greatest difference in EMG activity between crunches and use of the exercise machine was in the oblique muscles. Activity for the left and right oblique muscles was  $49\% \pm 11\%$  and  $34\% \pm 12\%$  of maximum EMG activity during work on the machine against the highest load for rotation to the left, whereas during abdominal

crunches, it was  $19\% \pm 7\%$  and  $26\% \pm 12\%$  of the maximum muscle. Thus oblique activity was more than twice as high as that seen during standard crunches. Even for exercise against the middle load band (orange band), rectus and oblique activity was similar to the standard crunches. For the yellow band, muscle activity was about half that of crunches.

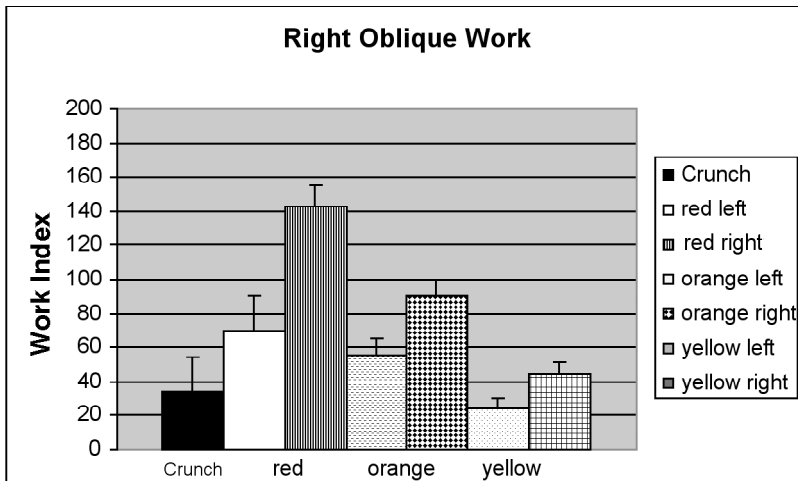
Not only was the EMG activity higher, but the duration of the exercise



A



B

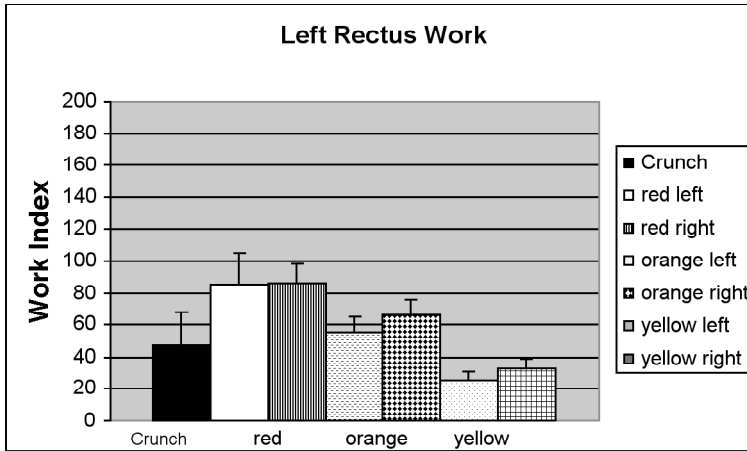


**Figure 6.** Illustrated here is the work during exercise for the (A) left oblique muscles, (B) right oblique muscles, (C) left rectus abdominis muscles, and (D) right rectus abdominis muscles for exercise at the heaviest work load during left and right rotational exercises (all using the exercise machine) compared with supine abdominal crunches. Work is calculated as the product of muscle activity  $\times$  the duration of the exercise. Since muscle activity is normalized to each person, it is in relative units. Data are shown for the yellow, orange, and red bands for the left and right muscle groups (left and right bars).

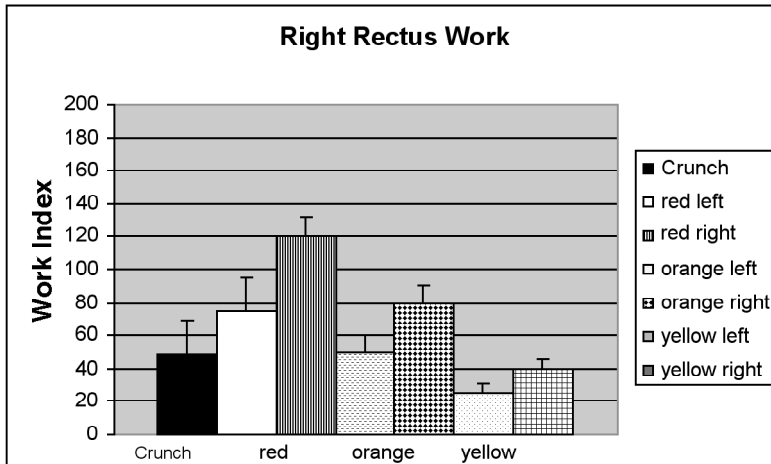
was longer using the exercise machine compared with abdominal crunches. The average duration of the exercise for all subjects was  $4.04 \pm 1.92$  seconds for the left rotation exercises,  $3.92 \pm 1.52$  sec-

onds for the right rotation exercises, and  $2.04 \pm 0.92$  seconds for the abdominal crunches. Thus, with a significantly longer duration of the exercise on the machine versus standard abdominal

C



D



crunches, work would also be greater for the machine on a per crunch basis. By multiplying the product of time by EMG-derived muscle activity, a work index was computed. This work index data are shown in Figure 6.

When work was computed for the left oblique (Figure 6A), right oblique (Figure 6B), left rectus abdominis (Figure 6C), and right rectus abdominis

(Figure 6D) muscles for exercise rotating left and right with the exercise machine versus supine crunches, the results show that work was much higher for any given exercise than supine crunches. As can be seen in this figure, the total work for exercise against the red band was 4.0 times higher on the Cross Crunch machine than for standard crunches. For the oblique muscles, work was 4.42 times greater during side exer-

cises versus standard crunches. For the rectus abdominis muscles, work was 1.7 times greater. A similar relationship was seen with the other bands, but with a lighter load, work was proportionally less. For the orange band, work for the oblique muscles was still 3 times greater than for standard crunches, while for the rectus abdominis, it was approximately equal to standard crunches. Total work of all the muscles was more than twice as high on the abdominal crunch machine versus standard crunches. For the yellow resistance band, work was about equal for the oblique muscles between the two types of exercise and 20% less for the rectus abdominis during Cross Crunch exercise compared with standard crunches.

## DISCUSSION

Lower back pain is a major problem in the United States today.<sup>1,2</sup> This is true not only of older individuals but young adults as well.<sup>4</sup> There is a strong correlation between weak abdominal muscle activity and back injuries,<sup>6,7</sup> but even in well-trained gymnasts, lower back pain can be a limiting factor.<sup>9</sup>

Numerous abdominal machines have been developed to prevent or reduce back pain.<sup>21</sup> Some machines have the subjects in the seated position while others mimic standard crunches in the supine position.<sup>21,23</sup> However, substitution of muscles during use of these machines is common and hinders true abdominal strengthening of the rectus abdominis and oblique muscles.<sup>25</sup> In this investigation, a new lightweight machine was evaluated, the Cross Crunch, which was ergonomically designed to perform crunches in the seated position.

Figure 6 shows that with the Cross Crunch machine, the work accomplished by the rectus abdominis and oblique muscles was up to 4 times higher than standard abdominal crunches. Three workloads were examined here: 30, 50,

and 75 lbs (13.6, 22.7, and 34 kg). Obviously, when doing a standard abdominal crunch from the floor, the only load being lifted is the weight of the body. In this study, subjects were able to work against a progressive load by changing the bands. This allowed for a progressive workout regimen to increase strength and endurance in the abdominal muscles. When exercise was accomplished against the greatest resistance (red band), work was much greater than could be accomplished in an abdominal crunch. Here, 10 side crunches against the red band was equivalent to 40 standard crunches, or with the orange band, 10 crunches would be equivalent to 20 standard crunches. But even for the weakest load, the work was similar to standard floor crunches. This is significant in that people with disabilities, the obese or poorly conditioned people who normally could not do floor crunches, may accomplish work in the seated position with the same or more work than standard floor crunches. Plus, the exercise, unlike abdominal crunches, exercised both the rectus abdominis and oblique muscles in one single exercise, whereas crunches condition principally the rectus abdominis muscles.

In summary, this type of exercise for rectus abdominis and external oblique muscles provides more work than standard abdominal crunches. It can be accomplished from the seated position, and at the work levels seen here, it can provide improved strength, flatter and firmer abdominal muscles, and greater stability for sitting, standing, and reaching.<sup>32</sup>

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