Core Muscle Use in Superficial and Deep Abdominal Muscles with a Crunchless Abs Video

Jerrold S. Petrofsky PhD, JD[1]
Michelle Prowse MS PT[1]
Gurinder S. Bains MD[1]
Anshul Sharma BPT[1]
Jennifer Batt BS[2]
Shashi Gunda MPT[1]

[1]*Department of Physical Therapy, School of Allied Health Professions Loma Linda University, Loma Linda, California*

[2]*Department of Physical Therapy* Azusa Pacific University Azusa, California*

KEY WORDS: exercise, core, exertion, EMG

ABSTRACT

With an increase emphasis in society on technical achievements, exercise is not a priority or part of daily life. As such, core muscles are weak and back injury is becoming a national health care problem in the United States. In the present investigation, the subjects were 5 males and 4 females whose average age was 26.5+/-4.5 years. These subjects evaluated a new type of exercise program. The exercise program was on video tape (Crunchless Abs) and lasted approximately 20 minutes. The exercises were specifically designed to exercise the superficial and deep core muscles together. Abdominal crunches only exercise one or two muscle groups. During the exercise, muscle use was evaluated using the electromyogram and 2 D ultrasound to evaluate which muscles are contracting. Seven exercises were examined here. For the 7 exercises examined, there was significantly more muscle use and greater work than for abdominal crunches. More importantly, muscle use included deep and superficial muscles and engaged many different muscles in differing areas of the core of the body. Work was as high as 622% that of an abdominal crunch with average work of 312% that of an abdominal crunch with the Crunchless Abs video. Thus, this program is a better workout than that seen with crunches.

INTRODUCTION

The abdominal core is complex and is composed of more than 12 muscle groups [1,2,3]. The core muscles are used to stabilize the back. Weak abdominal muscles are correlated with a high incidence of back injury[1, 2, 3]. The upper and lower back, due to the fact that it is composed of individual segments of the spinal cord, if not kept in the proper position, cause undue strain on ligaments, tendons, and muscles. Thus, the United States army uses core muscle strength as a predictor of back injury in

recruits4. Exercise of the core muscles are also used in patients with back injury to allow quicker healing[5, 6]. Obviously, for an acute back injury, other techniques need to be used such as the McKenzie Technique[7] and hydrotherapy[8]. Numerous pieces of gym equipment have been used to strengthen the abdominal muscles[9]. However, many of these commercial types of exercise equipment exercise only a few muscle groups[9]. Furthermore, busy schedules often make gym visits sporadic. Exercising should be done on a regular basis to be effective[10]. Therefore, many home programs have developed a core muscle exercise regime.[3, 13, 14, 15]. For example, medicine balls have been used historically for resistance training programs.[16, 17, 18]. However, while evidence is good for superficial muscle activity during crunches in the abdominal muscles, deep muscle use is lacking. The importance of the deep muscles such as the transverse abdominus are that they wrap around the central core protecting the internal organs and holding them inside the abdominal cavity, much like a girdle wrapping around the midsection. These both holds the midsection in alignment and the stomach flat while preventing adverse movement in the lower back which could lead to injury. Thus strengthening of these muscles improves posture and aids in gastrointestinal function [13,14,16,17].

In the present investigation, an exercise video was tested. The exercise video offered a unique targeted exercise for both the superficial and deep abdominals simultaneously. Thus, unlike standard abdominal crunches where usually only one or two muscle groups are exercising, this allowed for a greater core work out in less time and thereby made it more palatable to the consumer for home use.

***Table 1**- General characteristics of subjects*

Demographics	Age (yrs)	Height (cm)	Weight (kg)	BMI	% Body Fat
Mean	26.56	170.22	72.23	24.72	22.46
SD	4.56	6.67	16.36	3.91	5.04

Subjects

The subjects in this study were 5 males and 4 females in the age range of 25-37 years old. All subjects were free of back injuries, cardiovascular disease, and neurological injuries. The general characteristics of the subjects are shown in Table 1. The institutional review board at Azusa Pacific University approved all methods and procedures and all subjects signed a statement of informed consent.

Methods

Determination of Muscle Activity - To determine muscle activity, the electromyogram was used. It was recorded by two electrodes and a third ground electrode placed above the active muscle[19, 20, 21, 22, 23, 24]. The relation between tension in muscle and surface EMG amplitude is linear[20, 25]. Thus, the amplitude of the surface electromyogram was used effectively as a measure of activity of the underlying muscle by simply normalizing the EMG in terms of a maximal effort. Muscle activity was therefore assessed by first measuring the maximum EMG of the muscle during a maximal effort and then, during any exercise, assessing the percent of maximum EMG to calculate the percent of muscle activity[20, 21, 22]. The electrical output from the muscle was amplified with a biopotential amplifier with a gain of 5000 and frequency response which will be flat from DC to 1000 Hz (EMG 100C amplifier, Biopac Inc., Goletta CA). The amplified EMG was digitized with a 16-bit analog to digital converter and sampled at a frequency of 2000 samples/sec (MP 100, Biopac Inc., Goletta CA). The software to analyze the EMG was Acknowledge 3.8.1 (Biopac Inc., Goletta CA).

Measurement of Muscle Use

In addition to using the surface electromyogram to assess muscle use, ^{2}D ultrasound was used. Here, a high resolution 2-D

ultrasound (Sonasite 180+, Seattle, WA) was used to measure superficial and deep muscle use. By looking at the movement of the muscles and thickness of muscles by examining the striated appearance of the muscle on ultrasound, the extent of muscle use was evaluated. By using a linear probe, the fitness and the change in thickness of the muscle, during any given exercise, was measured showing the use of the muscles.

Exercises

Exercise was accomplished by a video for the following exercises.

Alternating Leg scissors:

Subject sat on the edge of a chair and leaned back with both hands either on the hips or grasping the edge of the chair. To begin the exercise, the subject plantar flexed one foot and flexed the hip, bringing the knee in toward the chest, and then they slowly lowered the leg back so that the toes just touched the floor. The exercise was repeated with the opposite leg (Figure 1a).

Feldenkrias Clock:

The subject began in the supine position, knees flexed approximately 45 degrees and the legs crossed at the ankles. The subject placed both hands behind their head and flexed the trunk so that the shoulders just came off the floor. They rotated the trunk from their right side, through the center, through the left side of their body and back to the floor. The exercise was also completed with the opposite leg crossed over (Figure 1b).

Kneeling facing chair:

The subject began by kneeling on the floor in front of a chair. The subject placed their elbows on the chair and lifted both knees slightly off the floor keeping the back straight. Emphasis was on keeping the abdominals tucked while the subject held this position (Figure 1c).

Modified pushup:

Subject began with their hands and knees on the floor. Both arms were extended directly below the shoulders (modified push up position), just over shoulder-width apart and the hands grasping a small folded towel on the floor. The subject began the exercise by slowly sliding one arm forward and back to the original position while maintaining the modified push-up position. The exercise was repeated with the opposite arm (Figure 2a).

Plank mountain climb:

Subject began in a prone push-up position with arms and legs extended. The exercise involved the subject slowly flexing the hip and knee toward the opposite shoulder and returning to the original push-up position. Emphasis was on keeping the back and abdominals flat during the exercise. The exercise is repeated with the opposite leg (Figure 2b).

Side-lying hips leg lift:

The subject began in side-lying on the lower elbow and knee. In the starting position, both knees were together and slightly flexed; the upper arm was bent with the hand on the hip. The exercise involved the subject lifting their body and extending the top leg so that only the elbow, forearm and lower leg remained on the floor. The exercise was repeated using the other side of the body (Figure 2c).

Towel digs:

Subject began in supine position with knees flexed to 90 degrees and heels placed on a small folded towel. To perform the exercise, the subject slid the heels away from the body by extending both knees and then bringing them back in to starting position (Figure 3a).

Standard crunches-

Standard abdominal crunches were performed with the subject laying initially on their back on the floor. The hands were placed crossed just below the neck. The subjects was asked to flex the trunk by about 30 degrees so that the upper back was lifted off of the floor.

Procedures

On any given day, when a subject entered the laboratory, demographics were taken. After demographics were taken, the sub-

Figure 1- This Figure illustrates three of the exercises performed by the subject in this study. The exercises were Alternating Leg scissors (panel A), Feldenkrias Clock (panel B), Kneeling facing chair (panel C).

Figure 2- *This Figure illustrates three of the exercises performed by the subject in this study. The exercises were Modified pushup (panel A), Plank mountain climb (panel B), Side-lying hips leg lift (panel C).*

Figure 3- *This Figure illustrates the towel digs exercise.*

Figure 4*- Illustrated here is the rectus abdominus muscles at rest (panel A) and during the plank mountain exercise (panel B).*

Figure 5- *This Figure illustrates the average work for the rectus abdominus, obliques, back extensors and latissimus dorsi muscles for the entire group of subjects +/- the appropriate standard deviation. Data shown is the work accomplished during a single exercise. The average work for all muscles is also shown as an additional bar. The exercise accomplished was the Alternating Leg Scissors exercise.*

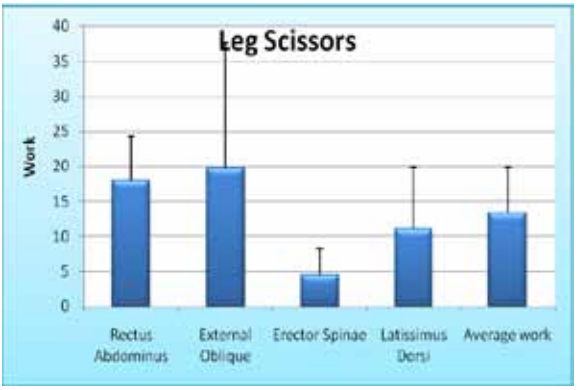
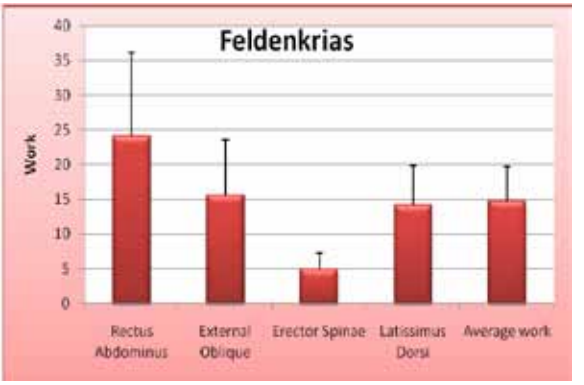


Figure 6*- This Figure illustrates the average work for the rectus abdominus, obliques, back extensors and latissimus dorsi muscles for the entire group of subjects +/- the appropriate standard deviation. Data shown is the work accomplished during a single exercise. The average work for all muscles is also shown as an additional bar. The exercise accomplished was the Feldenkrias Clock exercise.*



ject's skin was cleaned above the rectus abdominus, back extensors, right obliques and latissmus dorsi and electrodes were placed. The subject then was asked to exert a series of maximum efforts with one minute in between the contractions. During these maximum efforts, for each muscle group, the EMG response was measured. This was used in normalizing EMG data. Subjects then did a sequence of standard abdominal crunches. Finally, subjects were engaged in one minute bouts of seven different exercises while following the exercise video. During these one minute bouts of exercise, EMG was assessed to review muscle use in the superficial abdominal muscles. EMG was recorded from the rectus abdominus at L1, the back extensors at the level of L3, the latissimus dorsi at t7 and the right obliques.

Finally, also during one minute bouts, subjects again exercised, but here, ultrasound was used to evaluate muscle use. Ultrasound pictures were taken on the Sonasite 180 and then stored in memory for later analysis to observe changes in muscle thickness. Video streaming was done so that the muscle use could be evaluated. As illustrated in Figure 4 for the rectus abdominus, as exercise was accomplished, the rectus and other muscles thickened as they shortened. This was measured and recorded for each subject.

The exercises were (1) alternating leg scissors, (2) feldenkrias clock, (3) kneeling facing chair, (4) modified pushups, (5) plank mountain climb, (6) side lying hip leg lift and (7) towel dig. EMG was analyzed on the rectus abdominus, external obliques, latissimus dorsi and erector spinae. Ultrasound was assessed on these same muscles plus the transverse abdominus.

RESULTS

Using an electromyogram to assess muscle use, the peak muscle activity and average work for each exercise was assessed as shown in Figures 5-12.

Alternating Leg Scissors (Figure 5)

EMG analysis- For this exercise, the predominant muscle activity was for rectus abdominus muscles and the obliques. The peak muscle activity, as shown in Table 2. was 7.1% of the total muscle strength for these 4 muscles. The same relationship was seen when examining work. The average duration of the scissors was 2.45 +/-0.84 Seconds. This gave average work for one exercise cycle shown in the Figure and Table 3 and was 153% greater than for an abdominal crunch.

Ultrasound-

As shown in Table 4, the rectus abdominus shortened to 126% of its length while the obliques actually lengthened by 16%. Erector spinae and lats changed minimally in thickness. Generally, the change in thickness in the rectus was less than the crunch showing more isometric muscle activity here.

Table 2- *This Table shows the muscle use measured from a high resolution ultrasound for rectus abdominus, external oblique, latissmus dorsi, and transverse abdominus.*

Peak Muscle Activity									
		Rectus Abdominus		External Oblique		Erector Spinae		Latissimus Dorsi	
		Average	Normalized	Average	Normalized	Average	Normalized	Average	Normalized
Scissors	**Mean**	0.041	9.586	0.056	10.473	0.007	2.111	0.064	6.476
Felden	**Mean**	0.053	12.290	0.041	7.494	0.007	1.888	0.083	10.799
kneeling	**Mean**	0.101	20.263	0.074	13.374	0.009	2.564	0.071	7.852
push ups	**Mean**	0.035	7.956	0.046	8.659	0.006	1.792	0.108	11.382
plank	**Mean**	0.060	13.950	0.092	15.302	0.008	2.587	0.056	6.909
side	**Mean**	0.039	9.603	0.070	12.629	0.018	5.513	0.057	7.019
towel	**Mean**	0.033	7.247	0.049	9.083	0.020	6.032	0.204	21.182
crunch	**Mean**	0.076	18.603	0.082	13.688	0.005	1.654	0.035	5.076

Feldenkrias Clock (Figure 6)

EMG analysis- For this exercise, the predominant muscle activity was for rectus abdominus and external oblique muscles. The peak muscle activity is shown in Table 2 for the subjects. The average peak muscle activity was 8.1% of the total muscle strength for these 4 muscles. The same relationship was seen when examining work. The average duration of the abdominal crunches was 3.39 +/-0.62 seconds. This gave average work for one exercise cycle shown in the Figure and Table 3. The work was 169% greater than for an abdominal crunch.

Ultrasound-

As shown in Table 4, the largest change in thickness was for the rectus which contracted considerably. Erector spinae and lats were under the subjects and, due to body position could not be analyzed. Transverse abdominus stretched and were thinned to 55.4% of their initial length.

Kneeling chair (Figure 7)

EMG analysis- For this exercise, the predominant muscle activity was for rectus abdominus, lats and external oblique muscles. The peak muscle activity as shown in Table 2 was 11.0 % of the total muscle strength for these 4 muscles. The same relationship was seen when examining work. The average duration of the exercise was 6.1 +/-0.9 seconds. This gave average work for one exercise cycle shown in the Figure and Table 3. Work was 622% higher than for an abdominal crunch.

Ultrasound-

As shown in Table 4, the rectus and lats shortened while transverse abdominus lengthened. Transverse abdominus showed marked thinning, showing stretching of the muscle by about 50%.

Modified Push Ups (Figure 8)

EMG analysis- For this exercise, the predominant muscle activity was for 3 of the 4 muscle groups (external obliques, rectus abdominus and lats) by EMG analysis. The peak muscle activity is shown in Table 2 for the subjects. The average peak muscle activity was 7.4% of the total muscle strength for these 4 muscles. The same relationship was seen when examining work. The average duration of the exercise was 5.0 +/-1.21 seconds. This gave average work for one exercise cycle shown in the Figure and Table 3. Compared to a crunch, work here was 256% greater due to the longer and sustained duration of the exercise.

Ultrasound

With ultrasound as shown in Table 4, the rectus and lats shortened while transverse abdominus lengthened. Transverse abdominus showed thinning showing stretching of the muscle by about half.

Plank Mountain Climb (Figure 9)

EMG analysis- For this exercise, the predominant muscle activity was for rectus abdominus, external obliques and latissimus dorsi muscles. The peak muscle activity is shown in Table 2 for the subjects. The average peak muscle activity was 9.7 % of the total muscle strength for these 4 muscles with the peak of the obliques at 15.3%. The same relationship was seen when examining work. The average duration of the plank mountain was 3.94 +/-0.69 Seconds. This gave average work for one exercise cycle shown in the Figure and Table 3. Work was 299 % higher than for an abdominal crunch.

Ultrasound-

With ultrasound, external obliques showed the greatest shortening of any of the exercises. Here the shortening was significantly higher than for any other exercise ($p<0.01$). Rectus also shortened more than for any exercise ($p<0.01$). This matches the work calculated from EMG where exercise was hardest for this maneuver.

Side lying Hips (Figure 10)

EMG analysis- For this exercise, all 4 muscles were active during the exercise. The peak muscle activity is shown in Table 2 for the subjects. The average peak muscle activity was 8.69% of the total muscle strength for these 4 muscles. The same relationship was seen when examining work. The average duration of the side lying exercise

Figure 7- *This Figure illustrates the average work for the rectus abdominus, obliques, back extensors and latissimus dorsi muscles for the entire group of subjects +/- the appropriate standard deviation. Data shown is the work accomplished during a single exercise. The average work for all muscles is also shown as an additional bar. The exercise accomplished was the Kneeling Chair exercise.*

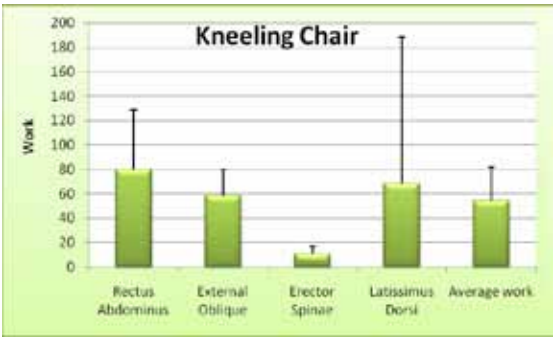


Figure 8- *This Figure illustrates the average work for the rectus abdominus, obliques, back extensors and latissimus dorsi muscles for the entire group of subjects +/- the appropriate standard deviation. Data shown is the work accomplished during a single exercise. The average work for all muscles is also shown as an additional bar. The exercise accomplished was the Modified Push Ups exercise.*

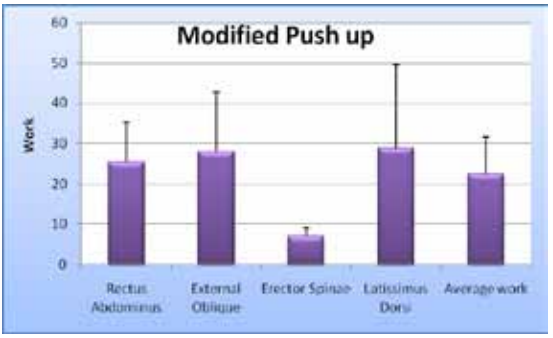


Figure 9- *This Figure illustrates the average work for the rectus abdominus, obliques, back extensors and latissimus dorsi muscles for the entire group of subjects +/- the appropriate standard deviation. Data shown is the work accomplished during a single exercise. The average work for all muscles is also shown as an additional bar. The exercise accomplished was the Plank Mountain Climb exercise.*

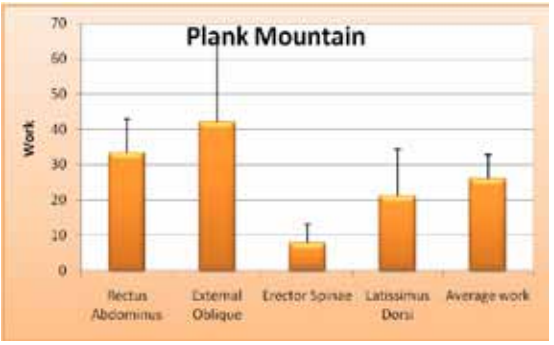


Figure 10- *This Figure illustrates the average work for the rectus abdominus, obliques, back extensors and latissimus dorsi muscles for the entire group of subjects +/- the appropriate standard deviation. Data shown is the work accomplished during a single exercise. The average work for all muscles is also shown as an additional bar. The exercise accomplished was the Side lying hips exercise.*

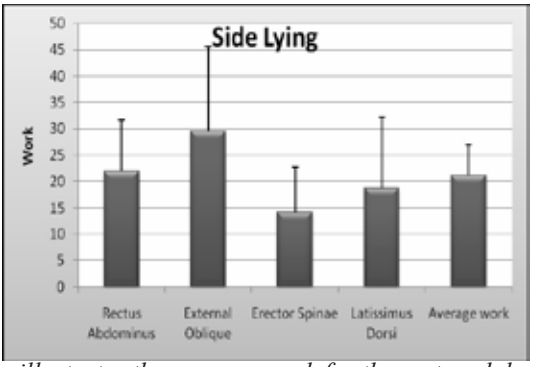


Figure 11- *This Figure illustrates the average work for the rectus abdominus, obliques, back extensors and latissimus dorsi muscles for the entire group of subjects +/- the appropriate standard deviation. Data shown is the work accomplished during a single exercise. The average work for all muscles is also shown as an additional bar. The exercise accomplished was the Towel Dig exercise.*

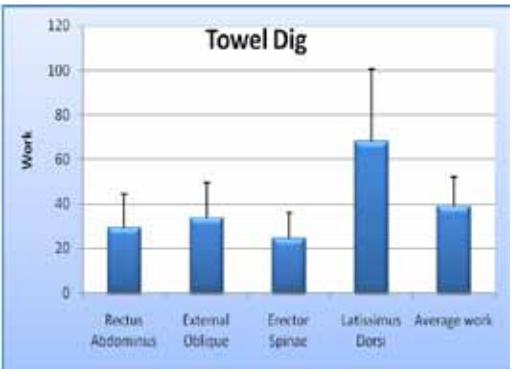
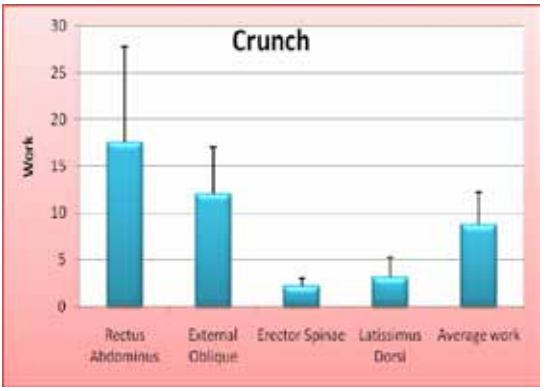


Figure 12- *This Figure illustrates the average work for the rectus abdominus, obliques, back extensors and latissimus dorsi muscles for the entire group of subjects +/- the appropriate standard deviation. Data shown is the work accomplished during a single exercise. The average work for all muscles is also shown as an additional bar. The exercise accomplished was an abdominal crunch.*



was 3.9 +/-1.2 seconds. This gave average work for one exercise cycle shown in this Figure and Table 3. Work was 242% higher here than for abdominal crunches.

Ultrasound-

All muscles worked equally as shown for work in Figure 10 as shown in Table 4. Transverse abdominus was stretched, as was the case in previous exercises.

Towel Dig (Figure 11)

EMG analysis- For this exercise, although all of the other muscles were also active, the predominant muscle activity was for latissimus dorsi. The peak muscle activity is shown in Table 2 for the subjects. The average peak muscle activity was 21.1+/-2.5% of the total muscle strength for these 4 muscles. The same relationship was seen when examining work. The average duration of the towel dig was 6.5 +/-1.7 Seconds. This gave average work for one exercise cycle shown in the Figure and Table 3. Because of the longer duration than for the crunches, the overall work was greater by 447% work for all of the muscles examined here compared to a crunch.

Ultrasound-

Only the rectus and the obliques were measured and worked equally well as shown for work in Figure 11 and shown in Table 4. However, external obliques were stretched and rectus contracted.

Abdominal Crunches (Figure 12)

EMG analysis- For this exercise, the predominant muscle activity was for rectus abdominus muscles (18.6%). There was very little activity on the back extensors , lattissimus dorsi or the obliques. The peak muscle activity is shown in Table 2 for all subjects. The average peak muscle activity was 10.9+/-2.1 % of the total muscle strength for these 4 muscles. The same relationship was seen when examining work. The average duration of the abdominal crunches was 1.6 +/-0.39 Seconds. This gave average work for one exercise cycle shown in the Figure and Table 3. As shown in this Figure, muscle work was largely for the rectus abdominus. Thus, as shown in table 5, the average work for all 7 exercises was 312+/-168% of the work of a crunch. For specific muscles, the average work of the 7 exercises examined were 187, 277, 483 and 1001 % higher than crunches for the rectus abdominus, obliques, erector spinae and the lattissimus dorsi muscles respectively. Thus a more balanced workout was seen with the crunchless abs video.

Ultrasound-

With ultrasound, as shown in Table 4, the largest work was for the rectus abdominus with considerable shortening. Erector spinae and lats were on the floor and could not be measured.

DISCUSSION

Back injury is a major healthcare problem in the United States today. [1, 2] The most effective way to prevent and treat back injury is strengthening of the core muscles in the body. [2,3] If there is a back injury, core training can increase the rate of healing.[5,6] There is also an added benefit of core training. A fit core helps increase posture and overall appearance.[31] Core exercise also increases precision of movement and economizes control of movement.[32]

Numerous studies have looked at different training protocols to see the effect on fitness scores, improving conditioning and muscle utilization26. To compare muscle use, electromyographic evidence has been used commonly[3, 4, 12, 27.] For example, in some studies, it has been shown that abdominal muscle activity is enhanced either with Swiss balls[29] or with stability balls [27]. Different types of abdominal exercises have been tested to see if there is a difference in muscle utilization[30]. However, because of limitations in using EMG surface electrodes, it is hard to tell specifically which types of exercise promote the maximum use of surface compared to deeper abdominal muscles. Further, since the transverse abdominus is located in the same plane as the internal and external obliques, it is hard to distinguish which muscles are used by which type of exercise with EMG.

In the present investigation, ultrasound was used as an adjunct to the EMG measurements. The exercise program evaluated in the present investigation was intended to exercise not only the rectus abdominus, as seen in traditional abdominal crunches, but the deep abdominal muscles as well. The exercises accomplished here were intended to use deeper muscles than a simple abdominal crunch. Abdominal crunches use very few muscles as seen in the present investigation. Crunches primarily train only the rectus abdominus (left and right), thereby effectively training only 2 muscles. This may lead to instability that can increase back pain. However, by using higher muscle utilization of deeper core muscles to stabilize the core, as in the present exercises, greater work and better core training should be found. Because of greater muscle use, such as in the obliques and latissimus dorsi, the average work for all 7 exercises was 312 % greater than that of a crunch. Some specific exercises showed even greater work. The kneeling chair used 622 % of the work of a crunch. Using this exercise as an example, for some individuals, work was 253 % greater than that of a crunch and for others it was as high as 1281 % that of a crunch. Thus for some people, these exercises were very difficult compared to a crunch. Other exercises such as Plank Mountain caused muscles such as the obliques to contract whereas others caused stretching. Crunches only cause movement of the muscle in 1 direction.

Thus, in the present investigation of a video program called "Crunchless Abs", there was a significant increase in muscle use in these exercises compared to a crunch. If assessed by EMG or ultrasound, these exercises, by combining significant core stabilization with each exercise, increased deep core muscle use as well as increased the use of upper as well as lower body muscles to stabilize the upper back as well as the lower back. EMG was sampled on only the superficial muscles. While a few muscles were added with ultrasound, subjects reported significantly more work in these exercises than crunches. Even for the muscles reported here by EMG or ultrasound, there was simultaneous use of many more muscles groups than for an abdominal crunch. In fact, 6 muscle pairs were used extensively in these exercises compared to 1 muscle pair during crunches. Therefore, with greater core stability in the entire back, posture should improve, back pain should be reduced and the future incidence of back injury should be reduced. Further, by using more of the deep core muscles simultaneously, the body is stabilized better and there should be less chance of injury during the exercise as well as a better overall workout. Better abdominal tone also flattens the abdominal area providing better posture and protection of the visceral organs.

REFERENCES

1 .Petrofsky JS, Bonacci J, Bonilla T, Jorritsma R, Morris A, Hanson A, Laymon M, Hill J. Can a one-week diet and exercise program cause significant changes in weight, girth and blood chemistry? J Appl Research, 2004; 4:369-375.

2. Petrofsky JS, Laymon M, Cuneo M, Hill J, Dial R, Pawley A, Morris A. A Bidirectional Resistance Device for Increasing the Strength and Tone in Upper Body Core Muscles and Chest Girth. J appl Res. 2005a; 5: 553-559.

3 .Petrofsky JS, Cuneo M, Dial R, Hill J, Morris A, Pawley A. Core Muscle Strengthening on a porTable abdominal machine. J appl Res 2005b; 5:460-472

4 .Szasz A, Zimmerman A, Frey E, Brady D, Spalletta R. An electromyographical evaluation of the validity of the 2-minute sit-up section of the Army Physical Fitness Test in measuring abdominal strength and endurance. Mil Med. 2002; 167(11): 950-3.

5. Baker RJ, Patel D. Lower back pain in the athlete: common conditions and treatment. Prim Care. 2005; 32(1): 201-29.

6. Powers DW, Wagner K. Getting back up from a back injury. Emerg Med Serv. 2004; 33(2): 82-3.

7. Slade SC, Ther MM, Keating JL. (2006) Trunk-strengthening exercises for chronic low back pain: a systematic review. J Manipulative Physiol Ther. 2006 Feb;29(2):163-73.

8. Konlian C. Aquatic therapy: making a wave in the treatment of low back injuries. Orthop Nurs. 1999; 18(1): 11-8; quiz 19-20.

9. Petrofsky, J.S., Morris, A., Bonacci, J., Bonilla, T., and Jorritsma, R. Comparison between an abdominal curl with times curls on a porTable abdominal machine. J Appl Res, 2003;3,394-401.

10. Health news. What happens when you quit exercising? The health of your muscles, your heart, and your mind quickly fades when you stop exercising.

2005;11(8): 14-15.

11. Le Bris S, Ledermann B, Topin N, Messner-Pellene P, Le Gallais D. High versus low training frequency in cardian rehabilitation using a systems medel of training. Eur J Appl Physiol. 2005;1-8.
12. Petrofsky JS, Morris A, Bonacci J, Bonilla T, Jorristma R. Aerobic training on a porTable abdominal machine. J Appl Res 2003b;3:402-415.
13. Petrofsky JS, Bonacci J, Conilla T, Jorritsma R, Morris A, Hanson A, Somers R, Laymon M, Hill J. Cardiovascular and fitness benefits of a one month home exercise and weight loss program. J Appl Res. 2004a;4: 610-624.
14. Petrofsky JS, Johnson E, Hanson A, Cuneo M, Dial R, Somers R, de la Torre G, Martinez A, McKenzie M, Forrester B. Abdominal and Lower Back Training in people with disabilities with a "6 second Abs" "Machine the effect on core muscle stability. Med Sci Mont. 2005c; 5,345-356.
15. Petrofsky JS, Cuneo M, Dial R, Hill J, Morris A, Pawley A. Core muscle strengthening on a porTable abdominal machine. J Appl Res 2005d;5:460-472.
16. Faigenbaum AD, McFarland JE, Johnson L, Kang J, Bloom J, Ratamess NA, Hoffman JR. Preliminary evaluation of an after-school resistance training program for improving physical fitness in middle school-age boys. Percept Mot Skills. 2007;104(2): 407-15.
17. Cochrane DJ, Hawke EJ. Effects of acute upper-body vibration on strength and power variables in climbers. J Strength Cond Res. 2007;21(2): 527-31.
18. Korsten-Reck U, Kaspar T, Korsten K, Kromeyer-Hauschild K, Bos K, Berg A, Dickhuth HH. Mortor abilities and aerobic fitness of obese children. Int J Sports Med. 2007.
19. Bigland B, Lippold O. The relation between force, velocity and integrated EMG. J Physiol 1954; 123:214-224.
20. Petrofsky JS. Frequency and amplitude analysis of the EMG during exercise on the bicycle ergometer. Europ J Appl Physiol 1979; 41,1-15.
21. Petrofsky JS, Lind AR. Frequency analysis of the surface EMG during sustained isometric contractions exercise. Europ J Appl Physiol 1980; 43:173-182.
22. Petrofsky JS. Computer Analysis of the Surface EMG During Isometric Exercise. Comp Biol Med 1980; 10;83-95.
23. Petrofsky JS, Dahms T, Lind AR. Power spectrum of the EMG during static exercise. Physiologist 1975; 18:350.
24. Petrofsky JS. Quantification through the surface EMG of muscle fatigue and recovery during successive isometric contractions. Aviat Space Environ Med 1981; 52:545-550.
25. Lind AR, Petrofsky JS. Cardiovascular and respiratory limitations on muscular fatigue during lifting tasks. Safety in Manual Materials Handling. International Symposium, State University of New York at Buffalo. 1978; 57-62.
26. Wescott WL, Annesi JJ, Skaggs JM, Gibson JR, Reynolds, O'Dell JP. Comparison of two exercise protocols on fitness score improvement in poorly conditioned Air Force personnel. Percept Mot Skills. 2007 Apr;104(2):629-36.
27. Sternlicht E, Rugg S, Fujii LL, Tomomitsu KF, Seki MM. Electromyographic comparison of a stability ball crunch with a traditional crunch. J Strength Cond Res. 2007 May;21(2):506-9.
28. Volbekiene V, Griciute A. Health-related physical fitness among schoolchildren in Lithuania: a comparions from 1992-2002. Scand J Public Health. 2007;35(3)235-42.
29. Marshall PW, Murphy BA. Increased deltoid and abdominal muscle activity during Swiss ball bench press. J Strength Cond Res. 2006 Nov;(4):745-50.
30. Chong RK, Bishop L, Collins W, Fielding A, Knight N. Comparison of muscle functions during three contrasting abdominal exercises. Percept Mot Skills. 2006 Oct;103(2):415-26.
31. Corrêa EC, Bérzin F. Efficacy of physical therapy on cervical muscle activity and on body posture in school-age mouth breathing children. Int J Pediatr Otorhinolaryngol. 2007 Jul 27; [Epub ahead of print]
32. Radziszewski KR. Physical exercise in treatment of patients with lumbar discopathy. Ortop Traumatol Rehabil. 2007 Jan-Feb;9(1):98-106.