Core Muscle Activity During Exercise on a Mini Stability Ball Compared With Abdominal Crunches on the Floor and on a Swiss Ball

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ABSTRACT

Ten subjects were examined to determine muscle use that occurred during core body exercise using a 7-inch diameter mini stability ball produced by Savvier LP (Santa Fe Springs, Ca) compared with abdominal crunches on the floor and on a Swiss ball. Muscle use was evaluated through the surface electromyogram recorded above the abdominal and lower back muscles. Three levels of core exercise were tested with the mini stability ball. The results showed that crunches on the Swiss ball used approximately 50% more muscle work per second of exercise as did work with the floor crunches. The lightest exercise (sitting crunches with the mini stability ball behind the back) was about equal to half of the work per second as floor crunches. However, the most intense exercises with the mini ball were as much as 4 times the work as abdominal crunches per second of exercise. The greatest difference in the mini stability ball exercise was seen when the degree of flexion/extension was increased from 50 to 90 degrees. This degree of flexion cannot be accomplished with standard floor crunches or with the Swiss ball (due to its larger diameter and size), thereby giving the mini stability ball a significant advantage in working the muscles harder and at a better range of motion.

Table 1. General Characteristics of the Subjects

Age (yrs)	Height (cm)	Weight (kg)
24.5 ± 2.3	172.7 ± 8.6	75.3 ± 14.0

All results given as mean ± standard deviation

By varying the angle of the back during the exercise, the mini stability ball had a wide range of exercise intensities that could be accomplished by the beginner, people with poor conditioning, or provide an intense workout for physically fit people.

INTRODUCTION

Core muscle exercise is common in training programs.[1,2] Typically, abdominal crunches are used to train the rectus abdominis and oblique muscles.[1,2] However, recent studies show that considerable muscle activity can be achieved with abdominal exercise devices including Swiss balls,[3,4] following exercise videos,[5] or both.

This type of exercise activity can have numerous benefits. These include stabilization of the core of the body,[6] reduction in lower back pain,[7,8] reduction in plasma lipids,[9] increased recovery and oxygen kinetics following exercise training,[10] improvement in function in cardiac patients,[11] better blood pressure control in stabilizing orthostatic intolerance,[12] and increased skeletal muscle blood flow, which has been linked to nitric oxide production.[13]

Although most of the studies concerning aerobic exercise involve running, cycling, skiing, and other types of sports,[14] considerable core and lower body activity can be achieved in many other types of exercise.[15] For example, abdominal core strengthening activity with a portable abdominal machine,[3,4] abdominal shaping machines,[16] or other abdominal training devices,[17,18] all cause core strengthening and muscle training.

The abdominal or core muscles, however, are unique. Strengthening these muscles not only has strong central effects in the body, such as cardiovascular training, but also causes an increase in stability of the trunk to extend during reach and functional activities.[19] These, in turn, reduce the risk of back injury. Lower and upper back injuries have always been a major problem in the United States and throughout the world.[20-23] Generally speaking, the first back injury usually occurs when people are in their twenties, but they do not experience a reoccurrence of the injury until their forties and fifties.[24,25] These back injuries cost the American public billions of dollars each year in medical care and lost wages.[26] They are especially taxing on the Worker's Compensation System in that they commonly occur in the work environment.[27,28] Numerous studies have shown that the core muscles in the body, in particular the abdominal muscles, are correlated to the incidence of back injury[29-31] because these muscles are used to stabilize the trunk; strength in these muscle groups stabilizes the spine and balance. For this reason, the United States Army uses core muscle strength as a predictor of back injury in recruits.[32]

Traditionally, abdominal crunches have been used to train the core muscles of the body.[17,18] But, abdominal crunches provide only low levels of muscle activity since the only resistance to core muscle activity is the body weight.[3,4,19] Therefore, large numbers of repetitions are needed to train. To increase muscle work, devices such as Swiss balls have been used as an adjunct to abdominal crunches. By performing exercise on a Swiss ball, there is decreased balance stability during exercise, thereby increasing muscle work in the core muscles.[33-35] The Swiss ball offers the advantage over floor crunches in that exercise on the Swiss ball allows a greater extension

Figure 1. Typical subject on Swiss ball.

Figure 2. Level 1 abdominal exercise is illustrated here with 30 degrees of flexion at the waist.

Figure 3. Subject accomplishing abdominal exercise with the mini ball and the hands above the knees.

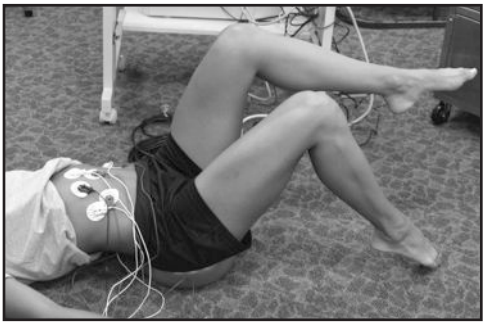

Figure 4. Subject accomplishing abdominal exercise with the mini stability ball under the upper gluteus muscle.

Figure 5. A subject performing exercise 1, level 3, with the mini stability ball.

Figure 6. Subject performing the level 3 wiper exercise with the mini stability ball.

during abdominal exercise compared with lying on the floor.[33-35] This offers considerable improvement over floor crunches but muscle activity is still not optimal for training. Therefore, a new mini stability ball was tested here in a variety of exercises to examine its ability to cause recruitment of the key core muscles during exercise. In the present investigation, the electromyogram (EMG) was used to assess muscle activity during exercise on a mini stability ball compared with the muscle use during abdominal crunches on the floor and on a Swiss ball.

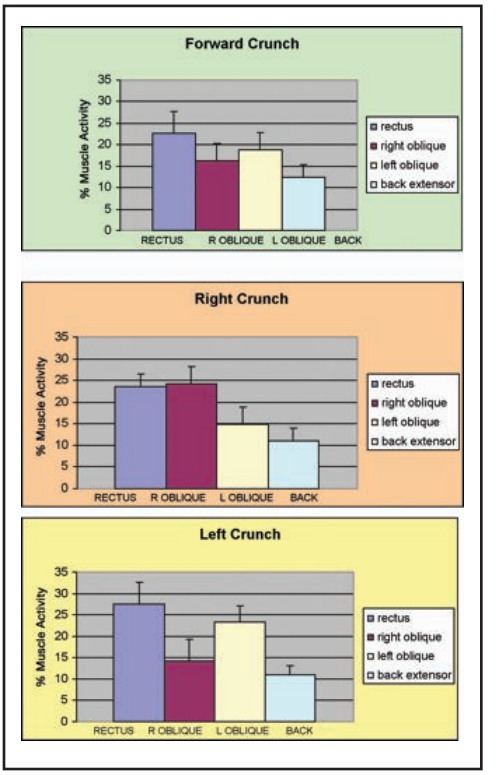

Figure 7. The muscle activity of the oblique, rectus abdominis, and back extensor muscles during abdominal crunches in the forward, left, and right directions during floor crunches. Muscle activity is shown for all 4 muscle groups examined as the mean ± the standard deviation for the group.

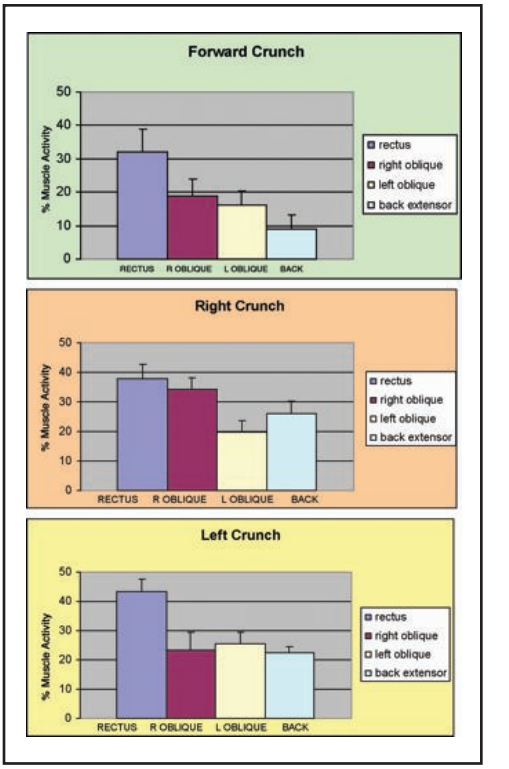

Figure 8. The muscle activity of the oblique, rectus abdominis, and back extensor muscles during abdominal crunches in the forward, left, and right directions during crunches on the Swiss ball. Muscle activity is shown for all 4 muscle groups examined as the mean ± the standard deviation for the group.

SUBJECTS

The subjects in this study were 3 male and 7 female subjects in the age range of 18 to 35 years. Subjects were fit and free of any cardiovascular, neuromuscular, or orthopedic injuries that would prevent their inclusion in these studies. All methods and procedures were explained to each subject who then signed a statement of informed consent. The studies and consent form were approved by the Human Review Committee at Azusa Pacific University. The general characteristics of the subjects are listed in Table 1. The number of subjects was chosen such that, based on the variance of the data in previous studies, statistical significance could be achieved as per power analysis.

METHODS

Determination of Muscle Activity

To determine muscle activity, the EMG was used. EMG was recorded by 2 electrodes and a ground electrode placed above the active muscle.[36-41] The relationship between tension in muscle and surface EMG amplitude is linear.[37,42] Thus, the amplitude of the surface EMG can be 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

Table 2. Comparing Data on the 3 Principal Muscle Groups for Floor and Swiss Ball Crunches. Each Point is the Corresponding *P* Value

	Rectus	Right Oblique	Left Oblique
Forward	0.03	0.53	0.65
Right	0.03	0.05	0.02
Left	0.02	0.05	0.05

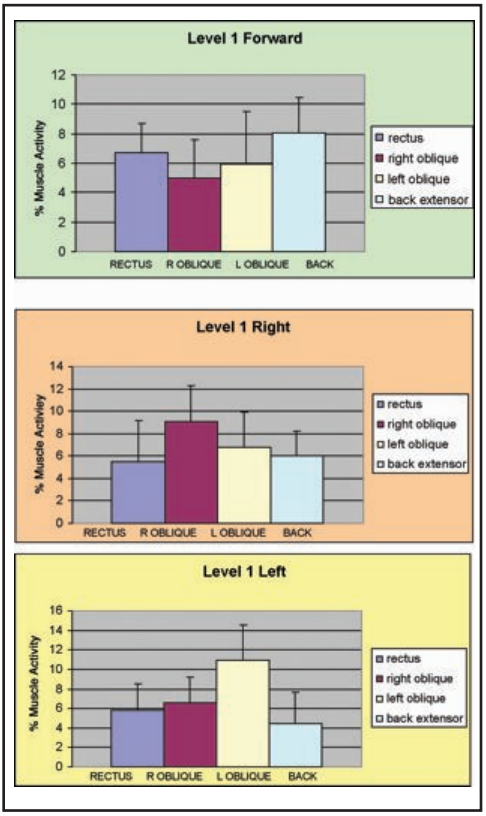

Figure 9. The results of the level 1 exercise. Muscle activity is shown for all 4 muscle groups examined as the mean ± the standard deviation for the group.

EMG of the muscle during a maximal effort and then, during each exercise, assessing the percent of maximum EMG to calculate the percent of muscle activity.[37,38] Two EMG electrodes were applied, 1 over the muscle and one 2 cm distal to the belly of the muscle. A third electrode, the guard, was attached within 4 cm of the 2 active electrodes. The electrode placement for the rectus abdominis was just above the umbilicus and parallel to the muscle fibers. The placement for the oblique muscles was 2 cm above the anterior superior iliac spine and at the pelvis of the posterior superior iliac spine for the back extensors and on and parallel to the direction of the muscle fibers.

The electrical output from the muscle was amplified with a biopotential amplifier with a gain of 5000 and frequency response that was flat from DC to 1000 Hz (Biopac Inc, Goletta, CA). The amplified EMG was digitized with a 16-bit analog-to-digital converter and sampled at a frequency of 500 samples/s (Biopac Inc.). The software used to analyze the EMG was Acknowledge 3.8.3 software on an MP100 system (Biopac Inc.). The amplitude of the EMG was analyzed by integrating the digitized data.

Exercise

Standard Floor Crunches

These were accomplished on the floor with the knees bent at 90 degrees, the hips at 45 degrees, the chest raised by 35 degrees of flexion, and the hands crossed on the chest. Standard floor crunches were accomplished in the forward flexion direction and with left and right flexion to a rotation of 30 degrees to exercise the oblique muscles.

Swiss Ball Crunches

A second set of exercises was accomplished on a Swiss ball. Here the subject sat on a ball (Figure 1). The subject then sat back with the hip extending to 0 degrees and then flexed to 90 degrees. The knees were at 90 degrees and the

Table 3. *P* Values Comparing the Level 1 Exercise With the Floor Crunches

	Rectus	Right Oblique	Left Oblique
Forward	0.000	0.002	0.000
Right	0.000	0.000	0.005
Left	0.000	0.027	0.004

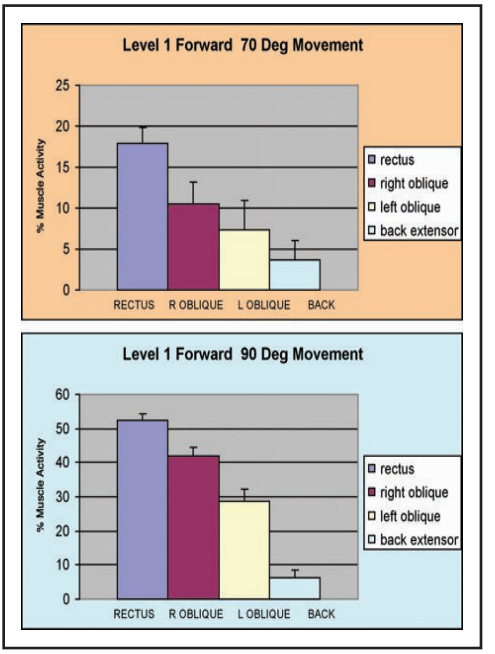

Figure 10. The muscle activity of the 4 muscle groups examined during level 1 exercise with the subject flexing forward where the movement flexed the back by 70 degrees (upper panel) and 90 degrees (lower panel) from the initial starting position. Muscle activity is shown for all 4 muscle groups examined as the mean ± the standard deviation for the group.

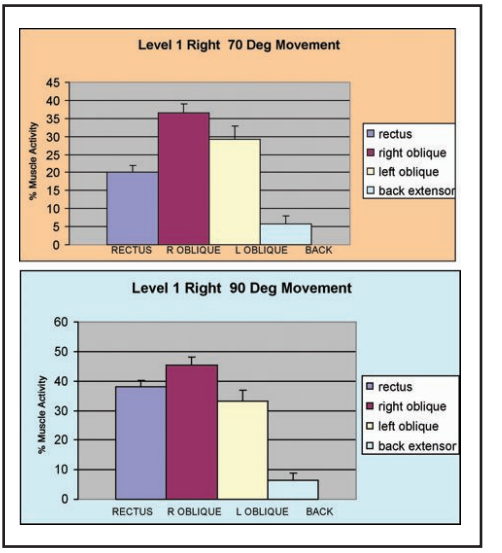

Figure 11. The muscle activity of the 4 muscle groups examined during level 1 exercise with the subject flexing to the right, where the movement flexed the back by 70 degrees (upper panel) and 90 degrees (lower panel) from the initial starting position. Muscle activity is shown for all 4 muscle groups examined as the mean ± the standard deviation for the group.

hands were folded on the chest. This exercise was repeated with the subjects facing forward and the trunk rotated to the right and left by 35 degrees.

Mini Stability Ball Exercises

***Level 1*:** There were 3 exercises in level 1. Subjects sat on the floor with the knees at 90 degrees and the hips initially at 110 degrees of flexion. The trunk was extended for the exercise and the mini stability ball (Savvier LP, Santa Fe Springs, CA) was placed against the sacrum (about 16 cm [7 inches]) in diameter placed at the mid sacrum) until, in different exercises, the back was extended to either 60, 40, or 20 degrees. The back was held in place for 1 second and then flexed to the initial position (Figure 2). By extending the back, for example, to 60 degrees from neutral, the angle at the back and hips was increased from 110 degrees of flexion to 60 degrees of extension or a total movement of 50 degrees. Thus the range of motion of the exercise was 50, 70, and 90 degrees for the 3 exercises. These exercises were repeated with the trunk rotated 35 degrees to the right and left to

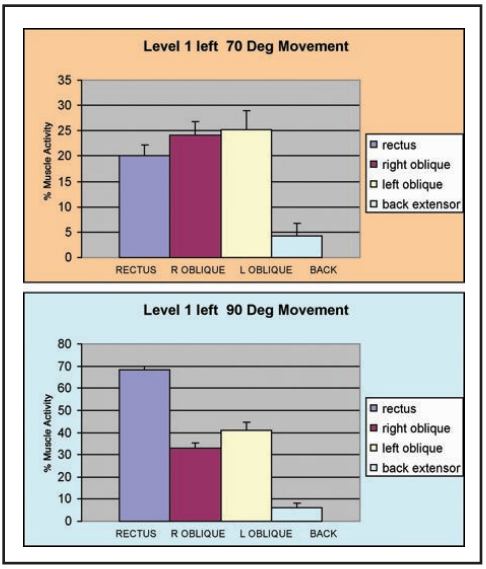

Figure 12. The muscle activity of the 4 muscle groups examined during level 1 exercise with the subject flexing to the left, where the movement flexed the back by 70 degrees (upper panel) and 90 degrees (lower panel) from the initial starting position. Muscle activity is shown for all 4 muscle groups examined as the mean ± the standard deviation for the group.

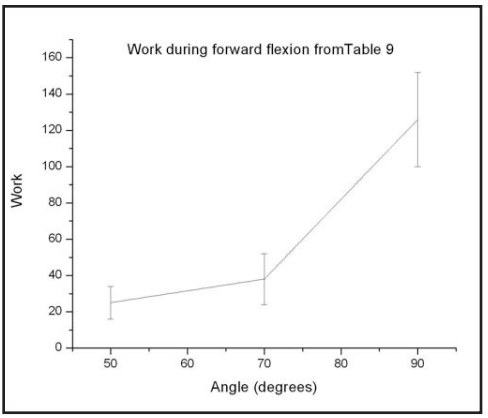

Figure 13. The work of the 4 muscles in the level 1 exercise with the flexion in the forward direction with flexion to 50, 70, and 90 degrees from the starting position. Muscle activity is shown for all 4 muscle groups examined as the mean ± the standard deviation for the group.

recruit the transverse abdominis and the oblique muscles. During these exercises, the hands were placed under the knees for support.

Level 2: There were 5 exercises in level 2. These consisted of first sitting on the floor with the knees at 90 degrees and the hips initially at 110 degrees of flexion. The hands were held in the air parallel to the floor. The back was resting against the mini stability ball and, the back was extended to 60, 40, or 20 degrees in different exercises, held for 1 second and then returned back to the initial starting position (Figure 3). This exercise was repeated with the trunk rotated 35 degrees to the right and left to exercise the transverse abdominis and the oblique muscles.

The final 2 exercises consisted of having the subject sit on the mini stability ball with the knees at 90 degrees and the hips at an angle of 90 degrees with the legs parallel to the floor. The legs were then alternately extended to touch the floor with the toes pointed as shown in Figure 4. The hands rested along the floor with the shoulder at 45 degrees for stability.

Level 3: There were 3 exercises in level 3 accomplished to the right and left side of the body. The first exercise consisted of having the subject sit on the floor with the ball behind his/her back. Here the hips were at an angle of 110 degrees and the knees at 75 degrees. The hands were placed behind the head and as 1 leg was flexed, the opposite elbow touched the knee as shown in Figure 5. This was performed on 1 side of the body and then the other. The second exercise was similar to the first but the movement was performed in rapid repetitions.

The third exercise, the wiper exercise (Figure 6), set consisted of placing the hands on the floor with the shoulders abducted 45 degrees to the side of the body for support and placing the ball between the knees with the hips and

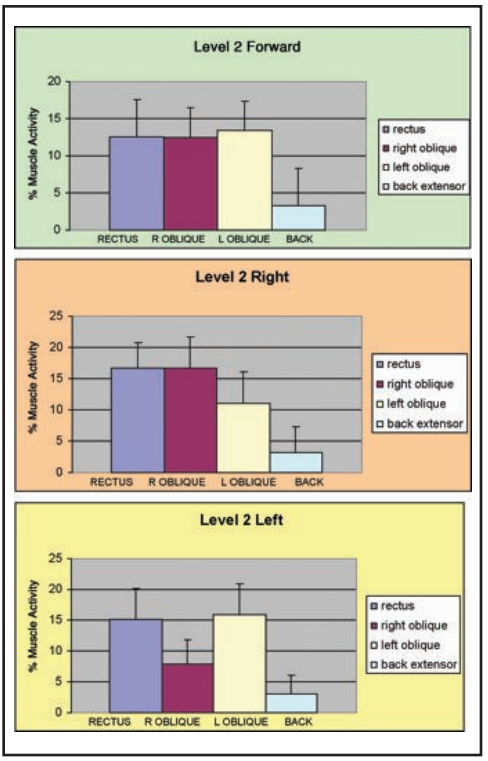

Figure 14. The results of the first exercise in level 2. Here the subjects held their arms parallel to the floor and did crunches forward (upper panel), to the right (middle panel), and to the left (lower panel). Muscle activity is shown for all 4 muscle groups examined as the mean ± the standard deviation for the group.

knees at 90 degrees. The hips were slowly rotated to the right and then the left through full range of motion.

Statistical and Data Analysis

Statistical analysis involved the calculations of means, standard deviations, and paired and nonpaired *t*-tests. The level of significance was $P<0.05$. To analyze work, a work index was calculated. This index used the average EMG and time to calculate a work index accomplished in 1 exercise cycle. The work of the 4 muscles was added together to give the total work for the muscles examined. Work was expressed as average work per second of exercise to make the exercises comparable because different exercises required different time periods to accomplish.

PROCEDURES

All subjects in the study were engaged in the same procedures. First, the EMG was assessed during a maximum effort for the 4 muscle groups examined. These were the right oblique, left oblique, rectus abdominis, and back extensor muscles. Next, abdominal floor crunches in the forward, left, and right directions were performed. This was followed by Swiss ball crunches. Finally, mini stability ball exercises were accomplished using a video for timing. For each exercise, EMG was sampled to assess muscle use.

RESULTS

Floor Crunches

The muscle use for the crunches performed on the floor is shown in Figure 7. The total work per each second of exercise (for all 4 muscle groups added together as work per second of exercise) was 54.1± 5.3 units per second for exercise facing forward (upper panel), 73.7 ± 4.8 units per second facing to the right (middle panel), and an average of 76.2 ± 9.3 units per second when facing to the left (lower panel). The greatest average muscle activity facing forward was for the rectus abdominis muscles averaging 23.3 ± 6.8% of maximum muscle activity. The greatest activity of the oblique muscles was seen when facing in the direction of the exercise as shown in the other 2 panels. The peak muscle activity for a 0.5-second period for the rectus abdominus, when exercising in the forward direction, was 76.1 ± 26.2% of the muscle, but the peak was short and was only at the greatest flexion point of the exercise. The oblique muscles, with the subject exercising facing the sides for the same 0.5-second period, showed 45.0 ± 22.7% of maximum muscle activity for the right-facing crunches and the right oblique muscles and 62.3 ± 24.5% of

Table 4. *P* Values Comparing the Level 2 Exercise at 50 Degrees of Flexion/Extension With Floor Crunches

	Rectus	Right Oblique	Left Oblique
Forward	0.002	0.007	0.0148
Right	0.002	0.007	0.0148
Left	0.005	0.060	0.050

maximum muscle activity for crunches facing to the left. The average duration of the floor crunches was 1.84 ± 0.52 seconds.

Swiss Ball Crunches

The muscle use for the 3 Swiss ball crunch exercises is shown in Figure 8. The average work index for the muscles (total work of all 4 muscles per second of work) was 76.3 ± 11.6 units per second for exercise facing forward, 117.6 ± 13.2 units per second for exercise facing right, and an average of 114.7 ± 15.2 units per second when exercising to the left. The greatest activity while facing forward was seen in the rectus abdominis muscles, which averaged 32.0 ± 14.4% of total muscle activity. The greatest activity of the oblique muscles was seen when facing in the direction of the exercise. The right and left oblique muscles showed peak muscle activity of 34.1 ± 12.2% and 25.5 ± 9.9% of maximum muscle activity in their respective directions. The peak muscle activity over a 0.5-second period at the peak of exercise during each crunch for the rectus abdominis muscle was 81.0 ± 14.2% in the forward direction, 58.8 ± 29.5% for the right oblique muscle in the right-facing direction, and 67.6 ± 37.3% for the left oblique muscle when exercising in the left-facing direction. The average duration of the crunches was 2.25 ± 0.34 seconds.

Swiss Ball Compared with Floor Crunches

The muscle activity of the 4 muscle groups examined was significantly higher during most corresponding exercise for the Swiss ball compared with the floor crunches as was the duration of the exercise as shown in Table 2. For the principal muscle movers for the 3 exercises and the total work done, the difference was significant.

Mini Stability Ball Exercises

Level 1

Fifty degrees of flexion/extension: The results of the level 1 exercise for 50 degrees of flexion-extension are shown in the 3 panels of Figure 9. The total work (work for all 4 muscle groups per second of exercise) was 25.7 ± 4.5 units per second for exercise facing forward, 27.4 ± 3.2 units per second exercising to the right, and an average of 27.8 ± 4.9 work units per second of exercise when facing to the left. The greatest average muscle activity facing forward was seen with the extensor muscles, which averaged 7.9 ± 3.1% of total muscle activity, and the greatest activity of the right and left oblique muscles was shown when facing their respective sides as shown in the other 2 panels. Muscle use was significantly less in the level 1 exercise than that in the floor crunches as shown for the 3 key muscles in Table 3. The average duration of the exercise was 5.41 ± 1.7 seconds.

The peak muscle activity of the rectus abdominis muscle measured over a 0.5-second period for the forward-facing exercise was 43.4 ± 9.5% of the maximum muscle activity. The peak activity of the muscle was 49.6 ± 24.1% and 55.3

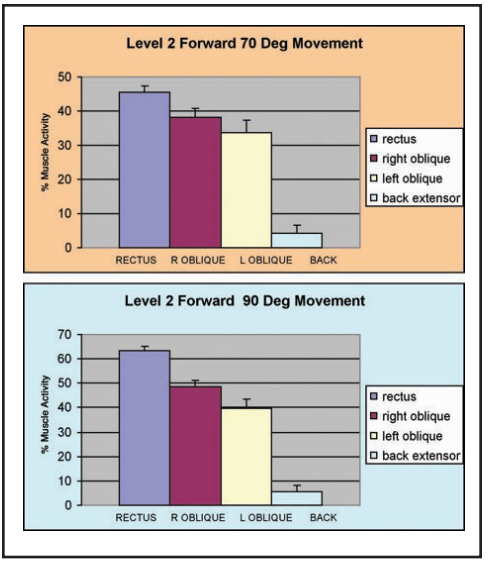

Figure 15. The muscle activity of the 4 muscle groups examined during level 2 exercise with the subject flexing forward where the movement flexed the back by 70 degrees (upper panel) and 90 degrees (lower panel) from the initial starting position. Muscle activity is shown for all 4 muscle groups examined as the mean ± the standard deviation for the group.

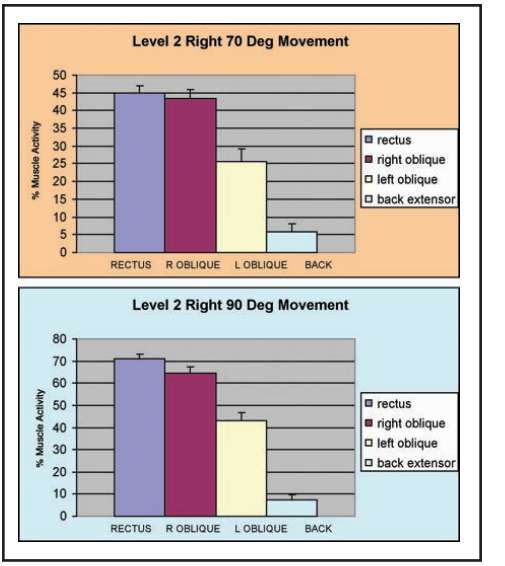

Figure 16. The muscle activity of the 4 muscle groups examined during level 2 exercise with the subject flexing to the right where the movement flexed the back by 70 degrees (upper panel) and 90 degrees (lower panel) from the initial starting position. Muscle activity is shown for all 4 muscle groups examined as the mean ± the standard deviation for the group.

± 25.9%, respectively, for the right and left oblique muscles for the corresponding side-bending exercises.

Exercise at 70 and 90 degrees of flexion extension: For a basis of comparison, Figures 10 through 12 show the muscle activity for 70 degrees of movement (upper panels) and 90 degrees of movement (lower panels) for exercise accomplished while facing forward (Figure 10), to the right (Figure 11), and left (Figure 12) sides. These figures show the average muscle activity of the 4 muscles examined here. Increasing the extent of flexion/extension from 50 to 70 and 90 degrees for any body position caused an exponential increase in muscle use. In fact, as an illustration, the calculated muscle work for the 4 muscle groups is shown in Figure 13. Here the work for the 4 muscle groups in each second of exercise increased from 25.7 units per second for 50 degrees of exercise to 38.8 units per second for 70 degrees of trunk movement, and 126.2 work units per second for the exercise facing forward at flexion/extension movement of 90 degrees. This increase was significant (ANOVA, $P<0.01$). Similar increases in work were seen for the other 2 exercise positions.

Comparing the muscle use and work for these exercises at flexion/extension of 70 and 90 degrees of movement, the muscle use and work were significantly higher than that of the abdominal crunches or the Swiss ball exercises ($P<0.01$).

Level 2

Exercise 1:

Fifty degrees of flexion/extension— The results of the first level 2 exercises at 50 degrees of flexion/extension are shown in the 3 panels of Figure 14. The total

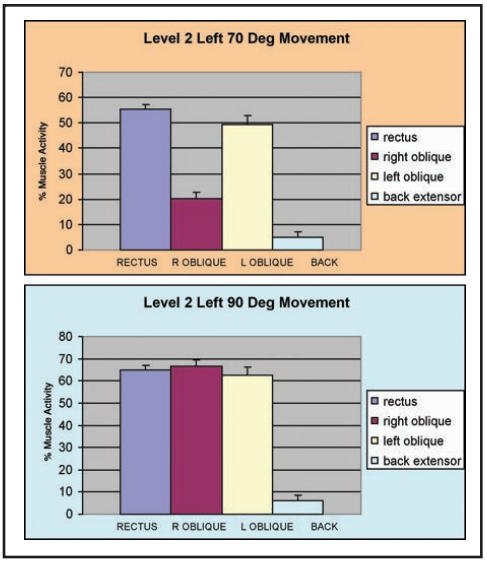

Figure 17. The muscle activity of the 4 muscle groups examined during level 2 exercise with the subject flexing to the left where the movement flexed the back by 70 degrees (upper panel) and 90 degrees (lower panel) from the initial starting position. Muscle activity is shown for all 4 muscle groups examined as the mean ± the standard deviation for the group.

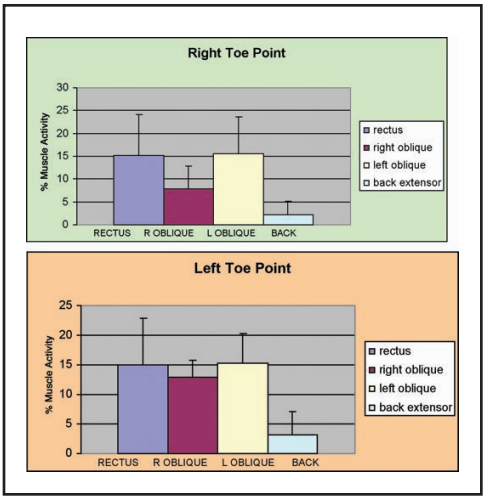

Figure 18. The results of the second exercise set in level 2. Here the subjects held their legs off of the floor and touched their toes to the floor on the right (upper panel) or left (lower panel) sides. Each point is the mean of the group data ± the standard deviation for the group.

work (for all 4 muscle groups in each second of exercise) was 41.7 ± 4.9 units per second for exercise facing forward, 47.5 ± 6.2 units per second twisting to the right, and an average of 42.0 ± 7.1 units per second when rotating to the left. The activity facing forward for the rectus abdominis muscles averaged 12.6 ± 5.1% of total muscle activity, while the greatest activity of the oblique muscles was when facing their respective sides as shown in the other 2 panels. The average duration of the exercise was 6.2 ± 0.68 seconds.

The peak muscle activity of the rectus abdominis muscle measured over a 0.5-second period was 68.4 ± 29.3% when facing forward. The peak activity was 59.9 ± 32.2% and 68.4 ± 30.7% for the right and left oblique muscles for the corresponding side bending exercises, respectively. Compared with the floor crunches, the muscle activity was significantly different for the key muscles in each exercise as shown in Table 4.

Seventy and 90 degrees of flexion/extension— As described above, when the exercise was extended to 70 and 90 degrees of flexion/extension, the exercise required considerably more muscle use and associated work. Figures 15 through 17 show muscle activity for 70 degrees of flexion extension exercise (upper panels), and 90 degrees of flexion extension exercise (lower panels) for exercise accomplished while facing forward (Figure 15), to the right (Figure 16), and left (Figure 17) sides. As can be seen here, increasing the extent of flexion/extension from 50 to 70 and 90 degrees for any body position caused an exponential increase in muscle use. This increase was significant ($P<0.01$). Similar increases in work were seen for the other 2 exercise positions. Comparing the muscle use and work accomplished with either the Swiss ball or floor crunches, the use and work were

Table 5. *P* Values Comparing the Level 2 Exercise With the Floor Crunches

	Rectus	Right Oblique	Left Oblique
Right	0.032	0.001	0.008
Left	0.041	0.009	0.046

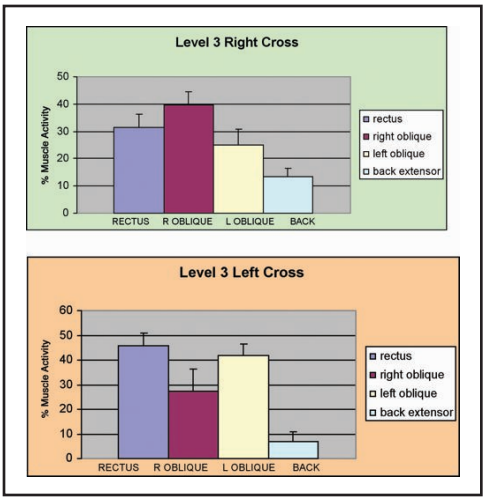

Figure 19. The results of the first part of the level 3 exercises. Here the subjects were in the abdominal crunch position with the ball behind their backs and alternatively touched their elbows to their knees on the right (upper panel) or left (lower panel) sides. Each point is the mean of the group data ± the standard deviation for the group.

significantly higher ($P<0.01$) for exercise at 50 and 70 degrees of back flexion/extension.

Exercise 2: The results of the second exercise in this sequence are shown in the 2 panels in Figure 18. The total work for the 4 muscle groups per second of exercise was 40.8 ± 5.4 units per second for exercise touching the right toes and 46.2 ± 6.2 units per second for touching the left toes. The average muscle activity during the exercise for the rectus abdominis muscle was 16.8 ± 14.3%, and 7.9 ± 4.5% and 17.7 ± 6.2%, respectively, for the left and right oblique muscles during exercise to the left and right sides. The average duration of the exercise was 6.1 ± 0.7 seconds.

The peak muscle activity of the rectus abdominis muscle measured over a 0.5-second period for the toe taps was 34.2 ± 16.3% when facing forward. The peak activity was 31.6 ± 8.9% and 41.2 ± 6.8%, respectively, for the right and left oblique muscles for the corresponding side tapping exercises. Compared with the floor crunches, the muscle activity was significantly different for the key muscles in each exercise as shown in Table 5. For the key muscles, muscle activity was significantly less for the crunches on the floor based on per second of exercise.

Level 3

Exercise 1:

Right and left cross crunch—The results of the first series of exercise are shown in the 2 panels of Figure 19. The total work averaged for each second of work for the 4 muscle groups was 109.1 ± 9.8 units per second for exercise touching the right toes and 121.9 ± 13.2 units per second for touching the left toes. The average muscle activity for the rectus abdominis muscle was 37.5 ± 11.2% for the right and left cross crunch exercises, and 37.4 ± 11.2% and 33.1 ± 12.1%, respectively, for the left and right oblique muscles during exercise to the left and right sides. The average duration of the exercise was 5.4 ± 1.6 seconds.

The peak muscle activity of the rectus abdominis muscle measured over a 0.5-second period was 69.3 ± 24.7% of the muscle when facing forward. The peak activity was 89.4 ± 15.1% and 57.1 ± 18.8%, respectively, for the right and left oblique muscles for the corresponding side tapping exercises. Compared with the floor crunches, the muscle activ-

Table 6. *P* Values Comparing the Level 3 Exercise With the Floor Crunches

	Rectus	Right Oblique	Left Oblique
Right	0.028	0.000	0.001
Left	0.002	0.001	0.001

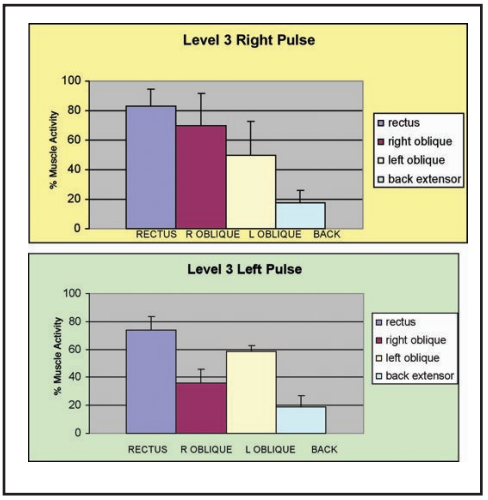

Figure 20. The results of the second part of the level 3 exercises. Here the subjects were in the abdominal crunch position with the ball behind their backs and alternatively touched their elbows to their knees on the right (upper panel) or left (lower panel) sides. Exercise here was a series of rapid pulses. Each point is the mean of the group data ± the standard deviation for the group.

ity was significantly different for the muscles in each exercise as shown in Table 6. For the key muscles, muscle activity was significantly greater than the crunches on the floor based on per second of exercise.

Exercise 2:
Left and right crunch pulse exercise— The results of the second exercise are shown in the 2 panels of Figure 20. The total work for the 4 muscle groups per second of exercise was 220.8 ± 28.4 for pulse exercises to the right and 187.0 ± 18.5 for pulse exercises to the left. The average muscle activity for the rectus abdominis muscle was 76.9 ± 27.4% for both the right and left exercises, and 41.7 ± 20.8% and 58.6 ± 14.2%, respectively, for the left and right oblique muscles during exercise for the left and right sides. The average duration of the exercise was 5.45 ± 0.98 seconds. The pulse exercise was one fifth of this duration, and for basis of comparison, the data from 5 exercises were added together and averaged for comparison with the other exercises in this series.

The peak muscle activity of the rectus abdominis muscle measured over a 0.5-second period was 76.9 ± 14.2% when facing forward. The peak activity was 53.2 ± 9.2% and 55.2 ± 7.3% for the right and left oblique muscles for the corresponding side tapping exercises. Compared with the floor crunches, the muscle activity was significantly different for the key muscles in each exercise as shown in Table 7. For the key muscles, muscle activity was significantly greater than for the crunches on the floor based on per second of exercise.

Exercise 3:
Left and right wiper exercise— The results of the first exercises are shown in the 2 panels of Figure 21. The total work for the 4 muscle groups was 33.8 ± 3.7 units per second for exercise to the right and 39.4 ± 2.9 units per second for exercise to the left. The average muscle activity during this exercise for the rectus abdominis muscle was 8.35 ± 4.5% of the maximum muscle activity, and 19.1 ± 11.2% and 15.1 ± 9.1%, respectively, of the maximum muscle activity for the right and left oblique muscles during exercise to the left and right sides. The average duration of the exercise was 5.6 ± 1.28 seconds.

The peak muscle activity of the rectus abdominis muscle measured over a

Table 7. *P* Values Comparing the Level 3 Exercise With the Floor Crunches

	Rectus	Right Oblique	Left Oblique
Right	0.002	0.001	0.005
Left	0.000	0.049	0.002

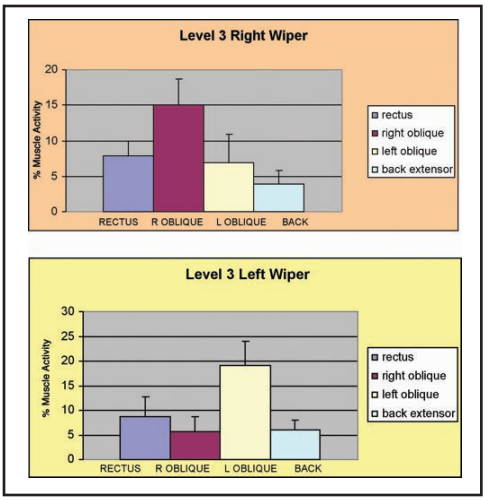

Figure 21. The results of the third part of the level 3 exercises. Here the subjects were lying on their backs on the floor with the ball between their knees and rotated their pelvis to the right (upper panel) or left (lower panel) sides. Each point is the mean of the group data ± the standard deviation for the group.

0.5-second period was 34.8 ± 15.4% when facing forward. The peak muscle activity was 78.9 ± 27.1% and 83.8 ± 39.2%, respectively, for the right and left oblique muscles for the corresponding exercises. Compared with the floor crunches, the muscle activity was significantly different for the key muscles in each exercise as shown in Table 8. For the key muscles, muscle activity was significantly less than that of the crunches on the floor based on per second of exercise.

Comparison of the Work for All Exercise with Abdominal Crunches and Swiss Ball Crunches

Table 9 shows a summary of the work for the various exercises. The extra columns for some of the exercises in level 1 and level 2 are for the extra exercises at 70 and 90 degrees of flexion extension of the trunk. Each number represents the average for all subjects of the total work of all 4 muscles examined per second of exercise. As shown in Table 9, the work per second of time for exercise with the mini stability ball varied from less than to many times greater than that used during floor crunches. Floor crunches required about two thirds of the work used for the same exercises on a Swiss ball. Mini ball crunches showed the greatest work at 90 degrees of flexion extension where work was as high as 2 to 4 times as much work as floor crunches. To show this relationship, Table 10 shows the percentage of work each exercise required compared with a forward facing floor crunch. The greatest work was shown with the level 3 pulse in the right-facing direction where work was 408% of that seen with the floor crunch.

DISCUSSION

Numerous benefits have been touted for aerobic exercise.[1,2] These include reduction in back pain,[43] better stabilization of the torso muscles for balance and reach,[44] reduction in blood lipids,[9] increased oxygen consumption in recovery following exercise,[10] and better overall fitness.[45] Although all types of exercise have good therapeutic benefits.[46] submaximal intermittent or continuous exercise seems to show the greatest benefits.[11,47]

One of the most effective types of exercise is core muscle strengthening. This form of exercise concentrates on the abdominal and lower back muscles.[29-31] The advantage of this form of exercise is that it can reduce lower back

Table 8. *P* Values Comparing the Level 3 Exercise With the Floor Crunches

	Rectus	Right Oblique	Left Oblique
Right	0.000	0.006	0.006
Left	0.001	0.043	0.043

Table 9. Total Work of Each of the Exercises Per Second of Exercise Time

	Total Work	70 Degrees	90 Degrees
Crunch Forward	54.1		
Crunch Right	73.7		
Crunch Left	76.2		
Swiss Forward	76.3		
Swiss Right	117.6		
Swiss Left	114.7		
Level 1 Forward	25.7	38.8	126.2
Level 1 Right	27.4	82.1	125.3
Level 1 Left	27.8	76.3	144.7
Level 2 Forward	41.7	122.7	156.9
Level 2 Right	47.5	119.8	188.7
Level 2 Left	42.0	132.9	202.6
Level 2 Toe Right	40.8		
Level 2 Toe Left	46.2		
Level 3 Cross Right	109.1		
Level 3 Cross Left	121.9		
Level 3 Pulse Right	220.8		
Level 3 Pulse Left	187.0		
Level 3 Wiper Right	33.8		
Level 3 Wiper Left	39.4		

pain and reduce back injury by allowing proper alignment of the spinal column.[29-32] Furthermore, functional reach can be increased with good core strengthening, reducing the risk of falling, especially in the elderly.[31]

In the present investigation, exercising with a 7-inch mini stability ball was used as a core muscle exercise program. Three levels of exercise were accomplished following an exercise video for timing. These data were compared with exercise with a Swiss ball and floor crunches.

The work and muscle use during floor crunches was significantly less for the key muscle groups for each exercise compared with the Swiss ball. Thus the total work was greater for any condition for the Swiss ball. This is probably because of the increase in muscle use of the core muscles to stabilize the body to balance on the Swiss ball compared with floor exercise[32-34] as well as the increased extension flexion by having the person elevated from the floor when exercising. With floor exercise, the floor provides stability; the Swiss ball removes this stability, which then must be provided by core muscle use. The Swiss ball provides greater extension and flexion but the extent of that movement is limited by the diameter of the ball; the larger the diameter, the less the movement. To gain

Table 10. The Level of Work of the Various Exercises Compared with Traditional Forward Facing Floor Crunches. Each Number is a Percentage of the Work of a Crunch

	Total Work	70 Degrees	90 Degrees
Crunch Forward	99.9		
Crunch Right	136.1		
Crunch Left	140.8		
Swiss Forward	141.0		
Swiss Right	217.4		
Swiss Left	211.9		
Level 1 Forward	47.4	71.7	233.3
Level 1 Right	50.7	151.8	231.6
Level 1 Left	51.3	141.0	267.5
Level 2 Forward	77.2	226.8	290.0
Level 2 Right	87.9	221.4	348.8
Level 2 Left	77.7	245.7	374.5
Level 2 Toe Right	75.3		
Level 2 Toe Left	85.4		
Level 3 Cross Right	201.7		
Level 3 Cross Left	225.3		
Level 3 Pulse Right	408.2		
Level 3 Pulse Left	345.6		
Level 3 Wiper Right	62.4		
Level 3 Wiper Left	72.9		

greater extension, the person would have to move off of the ball; this unsupported exercise is not recommended by trainers due to potential injuries because the back is not supported in a cantilevered position.

With the mini stability ball, these differences were enhanced further while still providing support for the lower back. While the muscle use and work on the Swiss ball and floor crunches were similar to that reported in other studies,[32-34] here the increased instability caused more muscle use in the oblique muscles compared with rectus abdominis muscles. This is demonstrated in exercises such as the forward facing exercise, where, during a floor crunch, only the rectus abdominis is the prime mover. Therefore, because the oblique muscles were used to stabilize the core while the rectus abdominis muscle was contracting, muscle use and total work were greater. Additionally, the smaller diameter ball allowed for greater range of motion during the exercise, increasing muscle use and work. This was especially true of exercise in level 2 at 90 degrees of flexion extension. Here the work was as high as 2 to 4 times greater than that of a crunch on the floor.

Although not measured in the study, the mini stability ball's diameter allowed for further extension than 90 degrees. Based on the exponential relationship in this study between extension/flexion and muscle use, this would further increase the exercise.

Similarly, the exercises in level 3, especially pulse right and pulse left, were already so difficult that higher levels of flexion extension were not studied, but would have lead to higher work.

One interesting observation was

that the mini stability ball created good back support in spite of its size. In Figures 9 and 10, when exercise was varied from 50 to 90 degrees, although the rectus abdominis muscle activity increased dramatically, there was almost no increase in back extensor activity. In fact, there was almost no back extensor activity seen, therefore allowing the isolation of the abdominal muscles while not increasing stress on the back muscles.

The variety of exercise here allows an unfit user to select low levels of work or a fit user to select very hard levels of work. Additionally, users can select to preferentially work different muscle groups to emphasize exercise on the rectus or the oblique muscles. A user with poor fitness can start easy and then progress over a range of 4 fold from the lightest mini stability ball work to the hardest, providing a good progressive workout for long-term training.

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