Aerobic Training During Abdominal Exercise With a Portable Abdominal Machine

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ABSTRACT

Four male and 4 female subjects participated in a series of experiments to determine the aerobic capacity of the abdominal muscles and to see if a portable abdominal machine called the 6 Second Abs machine could increase the aerobic endurance and strength of the abdominal muscles. Subjects were trained for 20 minutes per day 3 times per week for 3 weeks. Each training session involved accomplishing 6 second supine abdominal crunches with feet on a wall at a load adjusted to fatigue the subject in 20 minutes or less. When 20 minutes could be accomplished, the load on the abdominal exerciser was increased for the next training day. After 3 weeks of training, there was a 35.8 % increase in abdominal strength and an increase in VO_2max of 93%. Over the same period, the work accomplished during a 20-minute session increased by 66.9%. Thus by using a progressive resistance exerciser for abdominal training, a large increase in training of strength and endurance could be accomplished in a short time.

INTRODUCTION

Abdominal exercise is a common type of exercise done presumably to increase abdominal tone and strengthen the abdominal muscles as an aid in posture.[1-3] The main muscles involved during abdominal exercise are the transverses abdominis, external obliques, internal obliques, and rectus abdominis.[4] These muscles are involved in rotating and flexing the trunk. They also affect the lumbar spine by providing stability.[5]

However, in recent years, while a number of new types of commercial abdominal equipment have been developed, there seems to be no consensus on if or how well these machines can train the abdominal muscles. Abdominal exercise can be accomplished in the seated position with some of these exercise machines.[6,7] Other machines place the subject in the supine position. Whether an abdominal exercise is performed by a machine in the seated position or on the floor, there seems to be great variability in muscle activity during exercise. Substitution of other muscles is common and hinders training of only the abdominal muscles.[8] In a recent publication, Szasz et al[3] have questioned the use of

Table 1- General Characteristics of Subjects

Subject	Height (cm)	Weight (kg)	Age (yrs)	Sex
1	166	56.4	23	F
2	174	71.4	22	F
3	152.5	52.3	26	F
4	171	70.9	24	F
5	173	71.4	34	
6	173	72	23	M
7	178	71	24	M
8	182.5	87.3	29	M
Mean	171	69	26	
SD	9	11	4	

an abdominal physical fitness test by the United States Army because of substitution of hip flexors for abdominal muscles during standard supine crunches. The analysis of muscle use was accomplished through the surface electromyogram.[9]

Recently, we evaluated a new type of device called the 6 Second Abs machine. The device is in a rectangular frame with elastic bands that can be adjusted to increase load. By compressing the frame, abdominal exercise can be accomplished with a progressively increasing load.

When this device was evaluated, exercise was much more muscle specific for the transverse and rectus abdominus than other devices reported in the literature. For example, by rotating the trunk to the seated position, muscle use could be switched from the rectus abdominus when the subject was facing forward to the obliques when the trunk was rotated to the side. Using the electromyogram to evaluate muscle use with this device versus abdominal crunches, muscle use and total work was over 15 times greater during crunches with this machine than was found for standard abdominal crunches.[4] This was attributed to a combination of the device maintaining body position, providing timing, and providing progressive resistance exercise.

However, while the results were encouraging, we only studied strength and muscle use; the implication was that the machine would be better to train the abdominals than simple crunches or other devices but endurance studies were not conducted.

The purpose of the present investigation was to study endurance training with this machine and evaluate changes in strength and endurance compared to other reports in the literature. As a measure of aerobic capacity, VO_2max and lactate were assessed before and after training.

SUBJECTS

Four female and 4 male research subjects participated in these experiments. Table 1 lists the heights, weights, age, and sex of subjects.

METHODS

6 Second Abs Machine

The 6 Second Abs machine is a commercial exercise device (Savvier Inc, Indian Wells, CA). The device consists of a rectangular plastic frame with rubber bands on the inside to adjust resistance. Resistance can be increased in a number of different stages so that it becomes increasingly more difficult to compress the rectangle (Figures 1 and 2). As the machine is compressed to the first, second, and third click position, there is a linear increase in load. The upper part of the rectangle was placed under the subject's arms (under the triceps muscles bilaterally) or held in the person's arms against the chest, while the base of the rec-

Figure 1. Subject exercising in the seated position.

tangle was placed on top of the middle of the quadriceps muscles. Both the upper and lower rectangles are padded.

Measurement of Strength of the Abdominal Muscles

Isometric strength of the abdominal muscles was measured in both the seated position and the supine position. To accomplish this, initially subjects sat or lay with hips at a 90º angle. A cotton strap was placed around the chest and connected to an isometric string gauge transducer. The strain gauge was linear from 0 to 200 kg of force. The output of the transducer was amplified with a strain gauge conditioner amplifier with a gain of 1000 times and digitized in a Biopac 12 bit analog to digital converter and displayed and stored on an IBM computer. The output was stored and analyzed as the average

Figure 2. Subject exercising in the supine position.

strength over the middle of a 3 second contraction. Strength was measured by an isometric contraction with various angles at the hip to examine the relationship between muscle strength and position of the hip. At least 1 minute was allowed between contractions to allow for recovery.

Oxygen Consumption, Ventilation, Carbon Dioxide Production and Respiratory Quotient

A VO-2000 portable metabolic cart (Aerosport Inc, Minneapolis, Minn) was used in these studies. The analyzer is a battery operated metabolic cart containing a carbon dioxide infrared analyzer, a fuel cell based oxygen analyzer and a pneumotach. The analyzer was calibrated with the local barometric pressure and temperature at the beginning of each run. The analyzer then sampled expiratory gases through a mouthpiece. Since a mouthpiece was used, the subjects wore a nose clip. The gas was sampled breath by breath and all gas values were averaged over a 20 second period. Ventilation, oxygen consumption, and carbon dioxide production were then converted to standard pressure and temperatures and stored in the memory of the analyzer.

Blood Lactate

An Accusport fingertip lactic acid analyzer (Accusport Inc, Saint Paul, Minn) measured blood lactate. The analyzer was then calibrated daily with 2 control strips to ensure reliability of readings. The blood sample was taken from arterialized blood from the subject's fingertip, with a total blood sample of 25 μL. This sample was taken 5 minutes after the subject stopped exercising.

Heart Rate

Heart rate was monitored from a continuous electrocardiogram using a Polar Heart Rate Monitor (Aerosport Inc, Minneapolis, Minn).

Statistical Analysis

Statistical analysis involved the calculation of means, standard deviations, and paired and unpaired T tests. The level of significance was $P<0.05$.

PROCEDURES

Preliminary Testing

On testing days each subject was brought into a thermally neutral room in which he or she rested for 10 minutes. Prior to training, the initial maximum strength of each subject was measured as described above. This was followed by measuring the VO_2max of the subjects. A modified Bruce protocol was used whereby the pace of abdominal exercise in the supine position with the 6 Second Abs machine was constant and the load was increased every 2 minutes by changing resistance bands. Increments for the stages were 20, 30, 40, 55, 70 and 110 lbs for males; and 20, 30, 40, 55, and 70 lbs for females. These were applied at 2-minute intervals until exhaustion. Thus, the test continued until the subject could no longer maintain the required power output.

During the incremental exercise, VO_2, VE, and RQ were measured every 3 breaths. Heart rate was measured every 30 seconds.

Lactates were measured before exercise and 5 minutes after exercise, as described above. During the 5 minute post exercise and for 5 minutes pre-exercise, in order to arterialize the blood, the subjects placed a hand in a 9 inch glass bowl three-quarters filled with 40º to 45º C water.

The results of the maximum test were used to determine the power outputs that corresponded to 65% of VO_2peak, which was the workload used during the exercise training on the first day.

Exercise Protocol

Over a 3-week period 3 times a week, each subject performed a 20 minute 6 Second Abs workout lying on the floor with feet against the wall at a 90º hip and knee angle, measured using the same landmarks with the goniometer, as previously described. Each subject started with the workload that would enable him or her to perform curls for the entire duration. The subjects trained on Mondays, Wednesdays, and Fridays. When each subject was able to complete the exercise for 20 minutes, the workload increased by 5 lbs at the next session of exercise. However, if the subject was unable to complete the full twenty minutes of exercise, due to fatigue, the same amount of resistance was used at the following session, until the subject was able to complete the full 20 minutes. At the end of first day's session and at the end of every week of training, all subjects' lactate measurements were taken, by the procedure previously described.

After the ninth training day, on an additional day, all measurements taken prior to training were taken again to see the effect of training on the cardiovascular system.

RESULTS

The results of the experiment are shown in Figures 3 to 6. Data has been grouped together for all male and female subjects. Each point in each figure is the mean of the 8 subjects. Figure 3 shows the strength of the lower back muscles before and after training. As shown in this figure, the strength of the group increased from 106 ± 74 lbs before training to 144 ± 72 lbs after 3 weeks of training. This increase was signif-

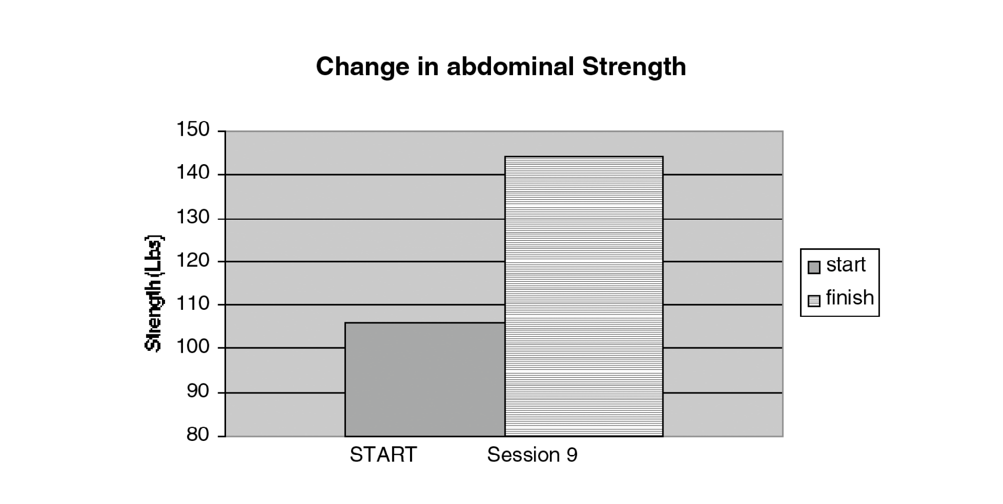

Figure 3. Abdominal strength in lbs at the start of the study and after 3 weeks of training.

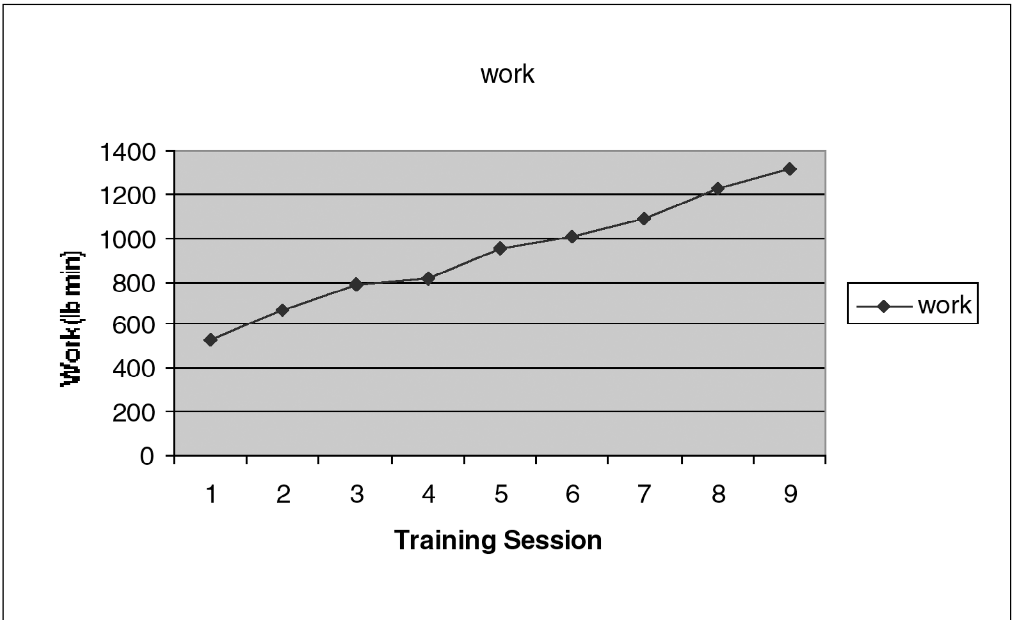

Figure 4. Work of the subjects for each of the 9 training sessions. Each point shows the mean of all subjects.

icant (P<0.01).

In a similar manner, endurance also increased. Since the length of the exercise session was limited to 20 minutes, the endurance of the session itself was fixed and not a measure of gains in aerobic capacity. But since the load for the work increased, if a 20-minute session could be maintained, the product of time and load (workload) was an effective measure of an increase in endurance capacity. The actual work then (force x distance) could be calculated as the product of load x time x distance moved. Since all subjects flexed their trunk by 30º (the third click of the abdominal machine), the distance moved was easy

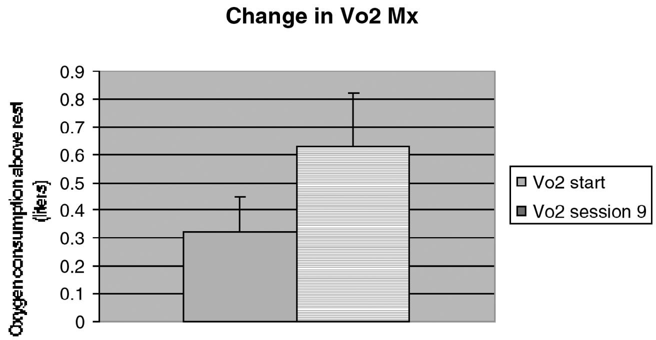

Figure 5. VO_2max of the groups of subjects before and after 9 sessions of training. VO_2 is above rest.

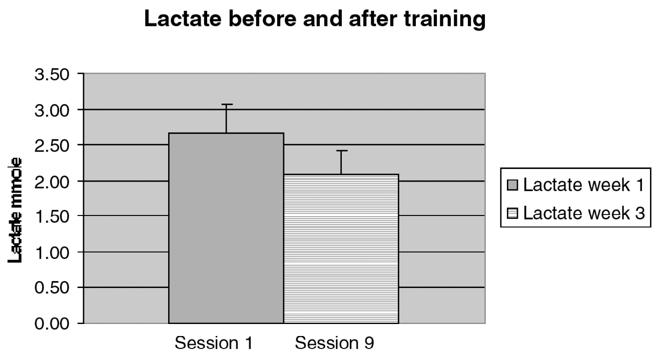

Figure 6. Lactate in the arterialized blood of the subjects after session 1 and after session 9 of training.

to calculate and work could be measured here. Using this measure, as shown in Figure 4, work at the beginning of training averaged 532 ± 169 lb minute and had increased to 815 ± 273 lb minutes by the fifth training day. By the end of the third week, the work was 1319 ± 217 lb minute. The increase in work was analyzed by ANOVA and was sig (P<0.001).

The increase in the work, which could be accomplished in a 20-minute period, was matched by an increase in aerobic capacity. As shown in figure 5, VO_2max increased from 320 cmL3 per minute above resting metabolism to 610 cmL3 above resting metabolism after 9 training sessions. The resting oxygen consumption before and after training was 210 and 190 cmL3 oxygen per minute respectively. Ventilation only increased by about 3 L per minute, when comparing results from before exercise training to after training. The maximum ventilation during the exercise was 6.41 L per minute above resting ventilation after training and 3.92 ± 1.2 L per minute above rest on the first day of training. Lactate was reduced with training by about 0.5 mmol per cmL3 (Figure 6). Maximum heart rate increased from 128 to 140 beats per minute after the 9 training days.

DISCUSSION

Numerous exercise devices have been developed for training abdominal muscles. For example, Thomas and Ridder[10] compared the effects of different abdominal exercise programs on abdominal muscular function and physique in 45 men and women. They found that either abdominal crunch weight machines, seated incline weight machines, or incline sit-up exercise all caused an increase in muscular power and flexibility. This would seem to show the validity of using machines such as these to exercise. But others have found that these machines are not very specific, and many muscles aside from the rectus abdominus and oblique muscles participate concurrently in the exercise.[3] The issue seems to be one of muscle substitution. If muscles can be substituted, training will train both the hip flexors and abdominals. If it is specific, only abdominal will be trained. In some applications like post surgical repair,[11] to reduce lumbar lordosis[12] or in restoring posture in disabled patients,[13] it is important to specifically train muscles for strength and endurance and not allow substitution.

Recently, we evaluated an abdominal exercise machine that fixes the position of the hips and upper body, and adds progressive resistance training for the abdominals. Electromyograph (EMG) studies, showed the device to be very muscle specific.[4] While the device was evaluated for specificity of muscle use, we did not attempt to train strength and endurance with prolonged use of the device.

In the present investigation, there was a large increase in work capacity with only 3 weeks of training. This seems to bode well for using this device for a training program. On the surface, however, the magnitude of the lactate response, either before or after training, seems to show little muscle use with this device. This is confirmed by the low heart rate, VO_2 and VE RESPONSE to the exercise, which is small compared to cycle ergometry or jogging. However, this may be a misinterpretation of the results.

It is well established that the VO_2max during jogging is about 4 L per minute in the average man.[14] In contrast, the VO_2max for arm work is about half. This is due to the fact that the muscle mass of the arms is less than half that of the legs. Further, during arm exercise, heart rate, VE and arterial lactates are also less during maximal work. This is due to the fact that the muscle mass is much smaller in the arms than the legs and, therefore, aerobic needs are smaller. Lactates, which may be very high in the venous affluent directly leaving active muscle, are diluted in the larger volume of body fluids. If we assume the VO_2max for leg work is 4000 cmL^3/min, then the $V0_2$/kg of a typical 70 kg man would be 57 cmL^3 per kg body weight of oxygen per minute. Numerous studies have pointed to aerobic capacity in well trained individuals in the range of 45 to 70 cmL^3/kg /min.[15,16] Assuming the muscles of the body weight 50% of the weight of the body, then the real v02 max of the muscles would be double this or 104 cmL^3/kg muscle per minute. But only about 50% of these muscles are active in lower body exercise, therefore the true VO_2 per kg active muscle would be double this again or 208 cmL3/kg muscle per minute. In the present study, the VO_2 after training was about 600 cmL3 above resting oxygen consumption. This would make the weight of the abdominal muscles at about 3 kg to require this amount of oxygen. This figure is probably close to reality for these thin muscle groups and would explain the low $V0_2$max presented here. Lawrenson et al[17] examined the VO_2max of the quadriceps muscle and found a value of 500 cmL3/minute gross VO_2. They did not, however, subtract resting oxygen consumption and therefore, their data support our hypothesis. Thus if the muscle mass was very small, aerobic capacity would be less as would VE, heart rate and Lactates. If the hip flexors and other muscles were substituted, then muscle mass would be large. The fact that they are small shows that little substitution has occurred and the muscles are isolated to just a few thin bands of muscle.

However, just a few weeks of training, doubled the aerobic capacity of the muscles. Lactates were reduced showing an increase in the anaerobic threshold. Thus the 6 Second Abs machine provided a good means of training the rectus abdominal muscles. In EMG studies, the obliques were not used to a large extent during a standard abdominal crunch. But use is very high with this machine and therefore, both muscles are trained here. Finally, only 1 exercise protocol was examined in this study. This is not to imply that other exercise protocols would not work as well. This study was not accomplished to determine the best exercise protocol, but to only evaluate aerobic training under one set of conditions. The dramatic results here are telling; this machine seems to offer an excellent aerobic training device.

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