A Bidirectional Resistance Device for Increasing the Strength and Tone in Upper Body Core Muscles and Chest Girth

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ABSTRACT

Considerable muscle weakness in the upper body is associated with the aging process. This can lead to upper and lower back strain and significant shoulder disabilities. A new type of portable exercise device was tested for strengthening and toning core muscles in the upper body such as the pectoralis major, pectoralis minor, and upper back extensor muscles, as well as scapular retractors. Two groups of subjects were examined using single-blinded, randomized study design. The control group (n=32) was examined twice to assess the reliability of the measurements; they did not exercise. Twenty-nine subjects participated in a 1-month exercise program involving 5 minutes of flexion/extension and horizontal abduction/adduction exercise using the arms to compress and extend an exercise device 5 days per week for a period of 1 month. At the beginning and end of the study, muscle strength, muscle tone, and girth were measured on the chest and back with a tensionometer and by a measuring tape. Ultrasound was used to measure muscle thickness on the chest and back.

In the control group, there was no significant difference in the first and second measurements. In the experimental group, strength of the shoulder horizontal adductors increased from 23.0 ± 6.3 to 29.1 ± 8.5 kg. Shoulder horizontal abductors, in a similar manner, increased from 24.3 ± 9.1 to 31.4 ± 9.4 kg. Associated with that increase was an increase in chest firmness from 0.89 ± .29 kg to depress the chest to 1.16 ± 0.29 kg. Back firmness improved by 0.35 ± 0.11 kg. Optical measurements of the chest wall showed an upward lifting of the breasts from the beginning to the end of the exercise period. In inches, initial chest girth was 36.4 (92.5 cm),

increasing to 37.2 inches (94.5 cm) after training. Muscle thickness increased by 0.26 ± 0.12 cm on the chest and 0.05 ± 0.12 cm on the back. Correspondingly, overall bust circumference increased by 1.95 ± 0.8 cm measured 6 cm below the axilla. The results showed that only 5 minutes of exercise per day on a resistance trainer can cause dramatic effects on core muscle strength, firmness, girth, and toning of the upper body.

INTRODUCTION

Strength training involving resistance exercise can have dramatic effects on preventing the loss of muscle strength and increasing muscle tone both in younger and older adults.[1] With resistance exercise, muscles respond within days showing an increase in both tone and muscle strength.[2] These types of exercise not only have a general benefit of increasing muscle strength and endurance, but can also increase oxidation of lipids, reduce body weight, reduce low-density lipoprotein cholesterol in the blood, and reduce fasting glucose.[3-5] Lifting weights slowly against a heavy load, called isokinetic exercise, even when conducted for short periods of time, can cause muscle enzymes to shift to glycolysis and increase the production of actin and myosin in muscle.[6-9] This allows the muscle to build strength and increase its ability to work with low-oxygen tension.[10] High-intensity resistance exercise is more effective than low-intensity resistance exercise to build isometric strength and increase the cross-sectional area of muscle even when exercise is only accomplished for as little as 2 weeks.[11] While a single protocol is effective, multiple protocols are more effective in building muscle strength.[12]

The side benefit of resistance training is in the ability to prevent injury.[13] It is also effective for patients with chronic heart failure in reducing some symptoms.[14] Imbalances in upper body strength around the rotator cuff, which can cause injury and pain, are easily reduced with resistance exercise.[15] Proper strength training in the upper core muscles, such as the back muscles, can also be effective as an alternative to surgery in reducing back pain as people age.[16] Upper body conditioning is also important in the treatment of reduced mobility at the shoulder[17] and preventing upper body osteoporosis.[18] Thus, for women, there are positive benefits in total health of the upper body caused by physical activity.[19] Upper body exercise has been considered good at reducing obesity.[20] More importantly, it has been shown to reduce the risk of breast cancer.[21-24] Upper body exercise can improve dynamic stability.[25] It is useful even after mastectomy and breast reconstruction.[26] Thus, weight-bearing programs not only reduce the decline in muscle strength[27] but also have significant medical benefits. Such cosmetic benefits of physical training can also have a dramatic effect on the well being of adults and reduce depression.[28]

One significant problem in women that is often overlooked is that as aging progresses, muscle weakness in the chest causes the breasts to sag. This in turn can create a lever arm that causes back and neck muscle strain and soreness. This has been a major problem in women. Rather than simply examining strength and endurance with exercise, the present investigation targeted an increase in chest firmness, muscle strength, girth, and body contours in the upper body in women before and after a 1-month upper body exercise program.

SUBJECTS

There were two groups of subjects. One group was composed of 32 women who served as controls. The other group, the exercise group, was made up of 29 women in the age range of 22 to 48 years old. All subjects were free of car-

Table 1. General Characteristics of Subjects (Group means)

	Age (y)	Height (cm)	Weight (kg)
Subjects	28.7 ± 8	163.3 ± 7.3	66.1 ±11.1
Controls	27.5 ± 7.2	165.8 ± 9.1	69.26 ± 11.2

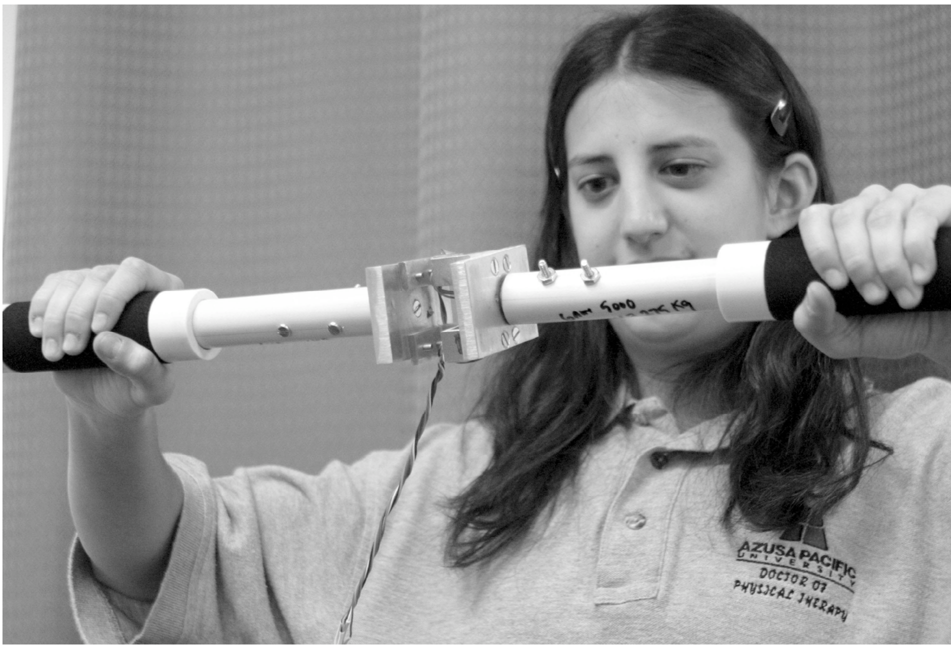


Figure 1. Upper body exercises modified for measuring strength.

diovascular disease and orthopedic injuries to the shoulders that would prevent them from participating in an exercise program. The subjects were randomly assigned to the control or the active group. The total number of subjects was sufficient to provide reliable results by statistical power analysis. All experiment procedures were approved by the Human Review Committee at Azusa Pacific University and all subjects signed a statement of informed consent showing their agreement to participate in these studies. Table 1 shows the general characteristics of the subjects.

METHODS

Isometric Strength

Isometric strength was measured on a modified exercise device consisting of a tube 85 cm long and 4 cm in diameter with strain gauges mounted in the center (Figure 1). The tube was held at chest level with one end in each hand, and force was measured during horizontal adduction and abduction of the shoulders. The shoulders were flexed to 90º during all measurements. Strength was measured on two occasions as 3-second maximum efforts with 1 minute between contractions. The average of the two was used for the maximum strength.

Measurement of Muscle Thickness

Muscle thickness was measured with a Titan two-dimensional ultrasound system manufactured by Sonosite, Inc (Bothel, WA). The device provided a weak ultrasound signal at a frequency of 10 million Hz. The ultrasound signal

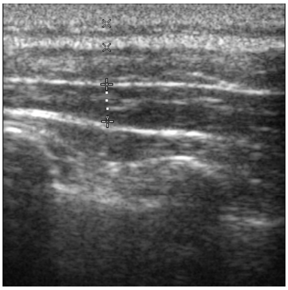


Figure 2. Typical ultrasound picture.

reflected from the muscles below the probe created a two-dimensional picture to measure the thickness of muscle. A typical picture is shown in Figure 2. The probe was placed at an angle of 90° with respect to the skin and used to measure the muscle thickness of the pectoralis and rhomboid muscles at the same location as the chest wall firmness measurements as described in the next section. For the rhomboid muscles, the arms were folded under the chin to place the muscle in a good anatomical position for measurement.

Firmness of Muscles

To analyze the resting tone of muscles in the chest and upper back, a tensionometer was used. The tensionometer consisted of a load cell, which was linear with an accuracy of ± 0.1% in a range of ± 5 kg (Omegadyne Corp., Stanford, CT model lc-23-205). The output of the load cell was amplified with a strain gage amplifier with a gain of 5000. This output was then filtered to allow band pass from DC to 20 Hz. The analog output was digitized with a 16-bit A/D converter by a Biopac MP100 system (Biopac Inc., Goleta, CA). The digitized data were then calibrated and analyzed at a later time. The load cell was connected to a flat post of 1 cm in length. The post was then extended through 3 different pieces of plexiglass that laid on the surface of the skin (Figure 3). This allowed the tensionometer to depress the skin by 2.5, 4.6, and 8.0 mm below the load cell. With these three depths, a graph was calculated for each subject showing the relationship between pressure and depth over each underlying muscle, with the muscle relaxed.

Exercise Device

The exercise device consisted of a pole 4.0 cm in diameter and 85 cm long. The device was manufactured by Savvier LP (Carlsbad, CA) and called the Bustmaster. The opposite ends of the pole had compression fittings consisting of O-rings such that by compressing the ends of the pole, air pressure was developed in the center. Since compressed air would not allow much movement at the opposite ends of the pole, a pressure release valve was in the center of the pole. When the pole was compressed, by regulating the airflow, resistance was regulated for compression and extension of the pole (providing bidirectional resistance). In practice, to push the opposite ends of the pole completely together took approximately 3 seconds with 3 seconds to extend the pole. Compressed, the pole was 52 cm long.

Girth

Girth was measured by a tensionometer applying 3 g of tension around the chest. Girth was measured just under the axilla and at 2, 4, and 6 cm below the axilla.

Photographic Measurements of Body Thickness

To see the contour of the upper body, a photograph of the frontal, back, and sagittal view of each subject was taken. A grid was projected from a photographic projector with spacing of 0.5 cm between the grid lines. The lines were red on a black background and the lights were turned off. Pictures were then captured. The camera was at a set

Figure 3. Muscle firmness measuring device.

distance from the subject and a set lens was used. A calibration was performed each day with a measuring scale that was flat and could be rotated horizontally and vertically by 22.5° and 45° to calibrate perspective.

Compliance and Exercise

Compliance was measured each day by an exercise log. Subjects also logged the workload used in the machine. The workload could be set to 6 different stages and subjects were encouraged to increase the workload as they could tolerate an increase during training.

PROCEDURES

All measurements were taken by technicians that were blinded, ie, the technicians did not know which subjects were in each group, thus providing a single-blinded, randomized study design. Baseline strength, girth, tissue density, and digital photo measurements of the control subjects were made on two different occasions as a measure of the repeatability of the measurements (no exercise was performed between the measurements). In the exercise group, after the same measurements, subjects exercised for 1 month. They exercised 5 times per week, 5 minutes per day for a period of 1 month. Control measurements involved measurement of muscle thickness over the pectoralis muscles and the rhomboids bilaterally. For the pectoralis muscles, measurements were made in the second rib interspace half way between the sternum and the midclavicular line bilaterally. With the rhomboid muscles, measurements were made 3 cm above the inferior angle midway to the spinal column bilaterally. Muscle firmness was measured at the same locations, at three depths so that a graph could be plotted relating pressure versus depth at each of the four locations. Digital photographs were also taken as described under the Methods section to establish thickness of the chest and

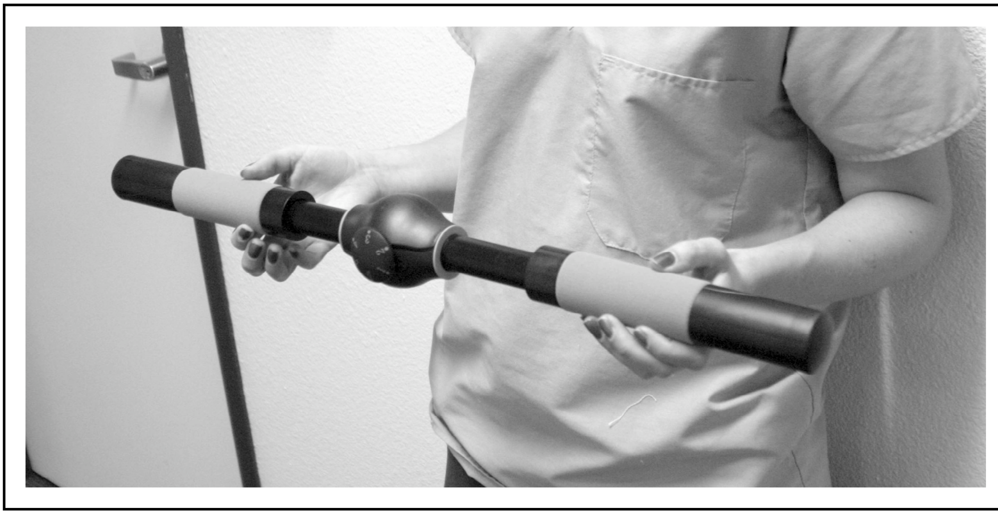
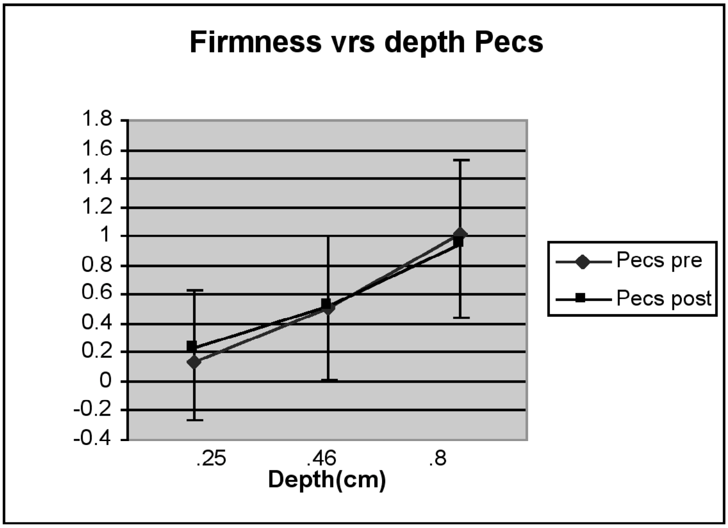


Figure 4. Subject during exercise.

anatomical position of the chest and back muscles. Girth measurements were also made as described under methods, and muscle strength was also tested.

Two series of exercises were accomplished during the month that were called sequences A and B. These were alternated daily (Figure 4). Each series required approximately 5 minutes to perform. For exercise sequence A, five different exercises were accomplished with 20 contractions (flexion/extension or horizontal abduction/adduction) of each exercise each day. The first exercise involved holding one arm above the other with the arms extended and the elbows locked. The shoulder muscles were then flexed and extended against the exercise device (Figure 4). In the second exercise in sequence A, the exercise was repeated, but with the arms reversed. In the third exercise in sequence A, the arms were extended, and the shoulders were at an angle of 90°. The shoulders were then horizontally adducted and abducted. In the fourth exercise in sequence A, the elbows were kept extended and the shoulders flexed such that the arms were at an angle of 130° with reference to the long axis of the body. The shoulders were then horizontally adducted and abducted for the exercise. Finally, for the fifth exercise in this series, the arms were lowered to an angle of 45° with the elbows extended and the shoulders were horizontally adducted and abducted.

Exercise sequence B also involved five exercises. In the first exercise, the elbows were extended with the arms extended such that one arm was 10° lower than the other arm. One arm, in effect then, was at an angle of 70° and the other at 120° at the shoulder and the exercise machine was compressed and extended. In the second exercise, the arms were reversed and the exercise was repeated. In the third exercise in the series, the elbows were bent at an angle of 90° and the shoulders also bent at 90° with reference to the body. Horizontal adduction and abduction were then accomplished at the shoulder. In the fourth exercise in the series, the elbows were extended, but the right arm was kept at the side with the left arm extending far enough forward to hold the exercise machine, and the machine was compressed and extended. The last exercise involved the same exercise but with reversal of the arms. The exercise load was increased each week to achieve training.



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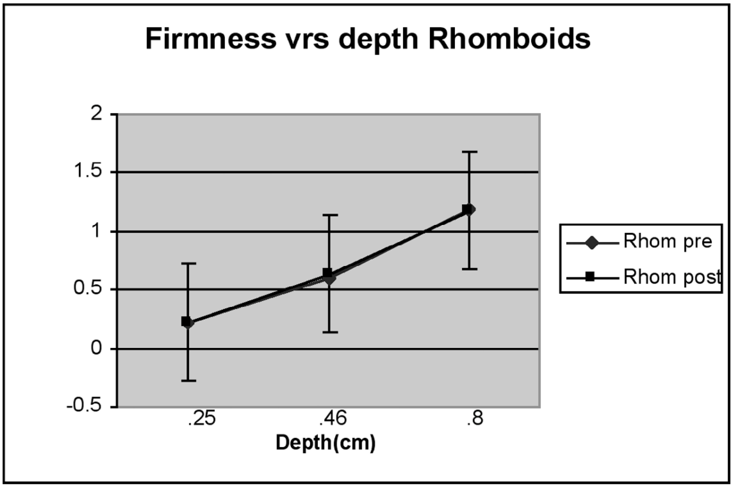


B

Figure 5. Firmness was measured as depression depth of the pectoralis major (A) and rhomboid muscles (B) versus tension to depress the chest or back wall. Data are shown before and after the control period.

RESULTS

For the control subjects, there was no significant difference in the pre and post measurements of strength, girth, muscle thickness, or chest dimensions by digital analysis. For example, Figure 5 shows the graphic relationship between depth and pressure for the pectoralis major

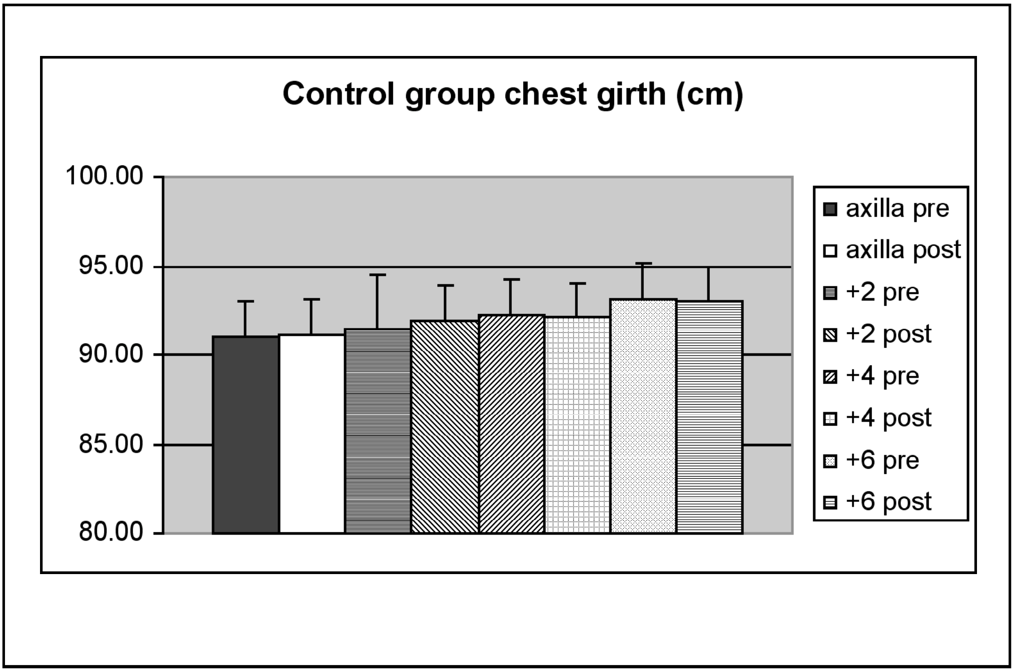


Figure 6. Girth measured before and after the control period.

and rhomboid muscles. Data for the group ± SD is shown before and after the control period. There was no significant difference between the data before and after the control period (*P*>0.05). The same was true for the girth measurements for the upper part of the body. As shown in Figure 6, while there were differences in the girth measurements before and after the control period, they were not significant (*P*>0.05). Another example is the digital body curvature measurements (Figure 7). The measurements went from cephalic to caudal, and the body contours are shown. There was no significant difference before and after the control period (*P*>0.05). Strength was not significantly different (*P*>0.05).

For the experimental group, the compliance of the subjects is shown in Figure 8. Compliance was on a 5-point scale. The subjects were instructed to work out 5 days per week. A score of 3 would indicate that they worked out 3 days in that week. Some subjects worked out 6 days per week and, therefore, their compliance score was above 5. As can be seen in this figure, compliance was 5.24 for the first week, 4.88 for the second week, 5.0 for the third week, and 5.12 for the fourth week. This gave an average compliance of 5.06.

Subjects were also instructed to increase the workload each week as they could tolerate the increased workload. The increase in the workload is rated in 1 to 6 since the device allowed work to be increased in 6 steps, with 6 being the heaviest. Figure 8B shows the increase in workload that, after the 4 weeks, had increased by 251%.

Given the high compliance and the increase in load, it was not surprising that strength increased for abduction and adduction. When comparing the strength for shoulder horizontal abduction and adduction before and after the 1-month training period, subjects showed a significant increase in muscle strength in the 1-month training period (*P*<0.01), with an average increase in

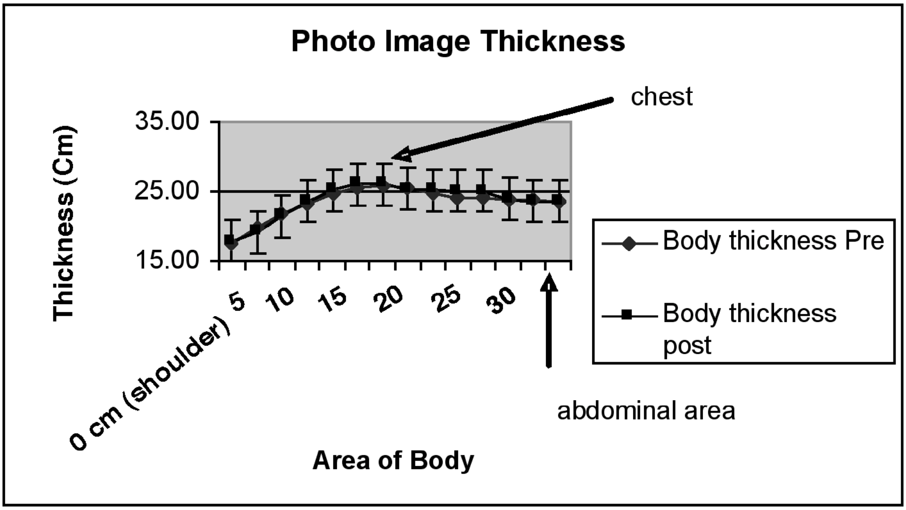


Figure 7. Digital measurement of chest size before and after control period.

strength from 23.0 ± 6.3 to 29.1 ± 8.5 kg for horizontal abduction and 24.3 ± 9.1 to 31.4 ± 9.4 kg for horizontal adduction (Figure 9A).

By using two-dimensional ultrasound, the muscle thickness of the pectoralis major and rhomboid muscles were measured (Figure 9B). The average muscle thickness increased from 0.87 to 1.12 cm for the average of the left and right side of the body for the pectoralis major muscles and, while the increase was smaller for the rhomboid muscles, for both groups the increase was significant ($P<0.01$).

This increase in muscle thickness and strength increased the firmness of the chest wall. Although subjects were fully resting during the measurements, when relating displacement distance to tension with a tensionometer described under the Methods section, the curve showed a significant increase. As shown in Figure 10A, for the pectoralis major muscles bilaterally on both sides of the chest, and Figure 10B for the rhomboids, there was a nonlinear increase in force associated with depression of the chest wall. After 1 month of training, muscle tone increased at the three different measuring depths as shown in each of the respective panels of this figure in the upper lines. These increases in resistance to depression at the three different measuring distances were all significant ($P<0.01$). For the greatest compression of the chest wall, firmness increased by 32% for the pectoralis major muscles and 24.5% for the rhomboid muscles.

Obviously, if muscle thickness increases, so should the girth of the body. The changes in girth are shown in Figure 11. As can be seen in this figure, there was an increase in girth of the chest by 1.95 ± 0.8 cm. The same was true for the distal measurements (Figure 12). The average increase in girth from the digitized picture measurements was 11.1%. In inches, initial chest girth was 36.4 (92.5 cm), increasing to 37.2 inches (94.9 cm) after training. Furthermore, firming in the upper body caused the breast line to rise (measured from digital measurements is the distance from the acromion to the nipple), an average

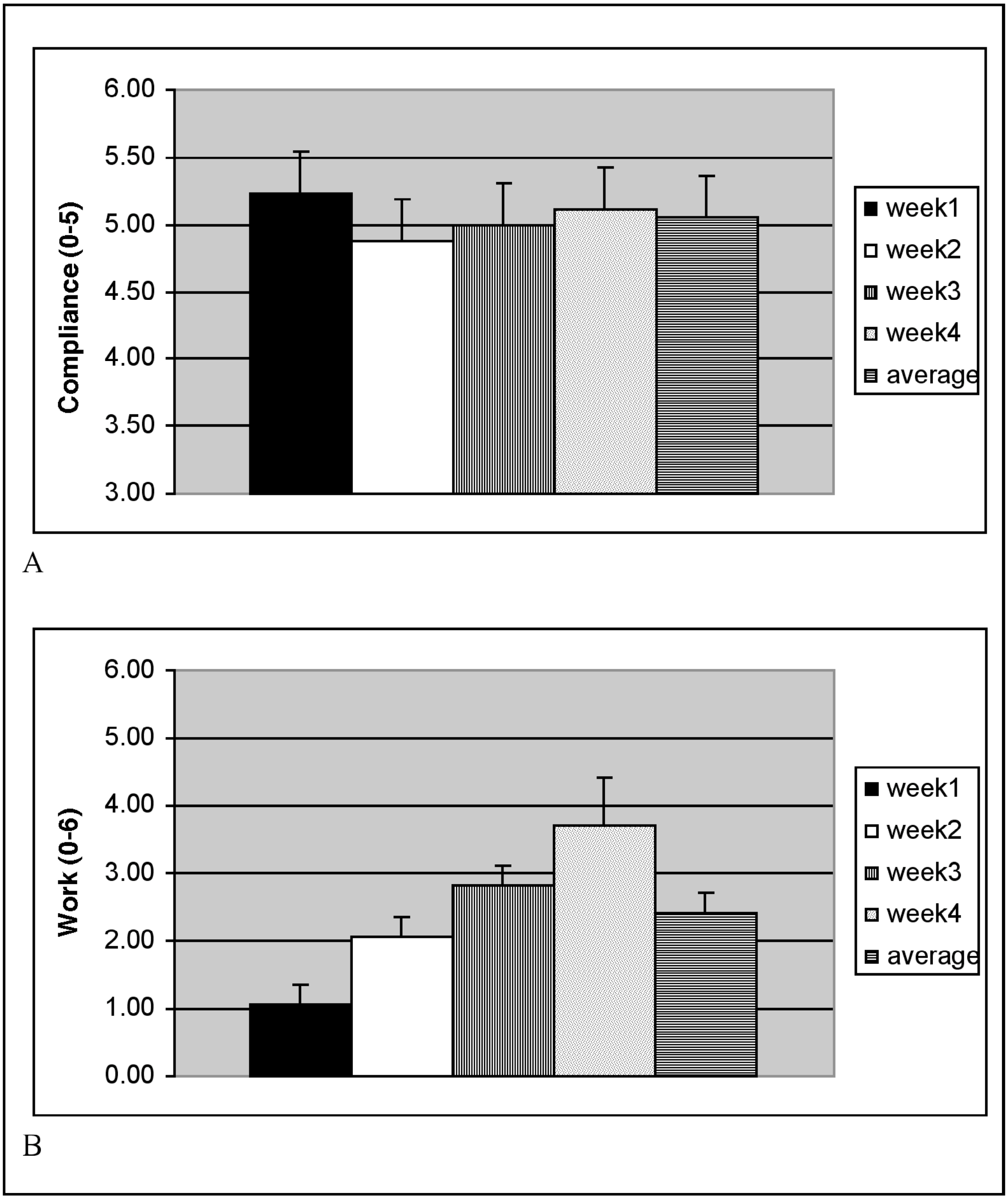


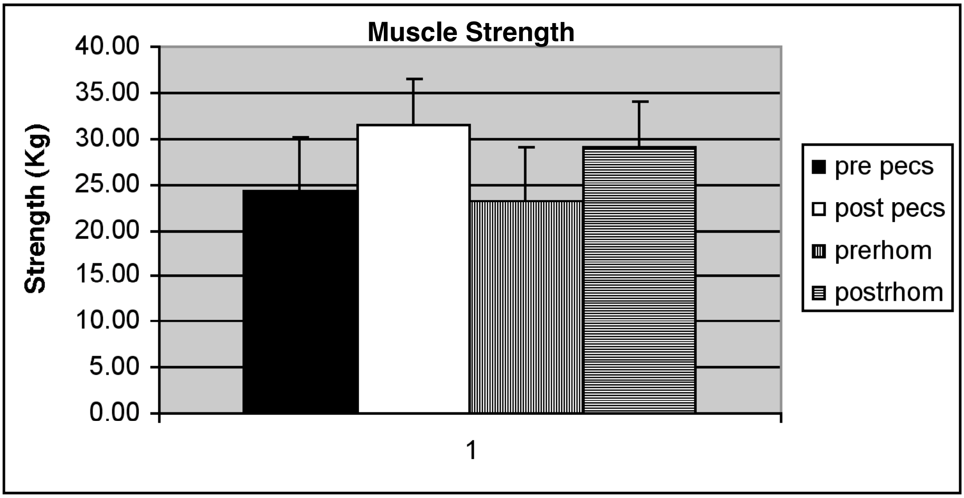
Figure 8. Compliance of the subjects for the exercise by the week is shown in panel A compared to the weekly average workload for the daily workouts in panel B.

of 0.45 ± 0.22 cm (Figure 13), ($P<0.01$).

DISCUSSION

There is long-standing evidence that exercise programs, even in geriatric patients, are beneficial to increase balance, strength, and reduce the incidence of falls.[29] Exercise not only increases muscle strength, but there is evidence that it improves the integrity of sensory nerve fibers in the skin and may contribute to whole body stability.[30] But even in younger individuals, exercise can reduce the incidence of back injuries, even in athletes.[31]

With resistance exercise, it is not



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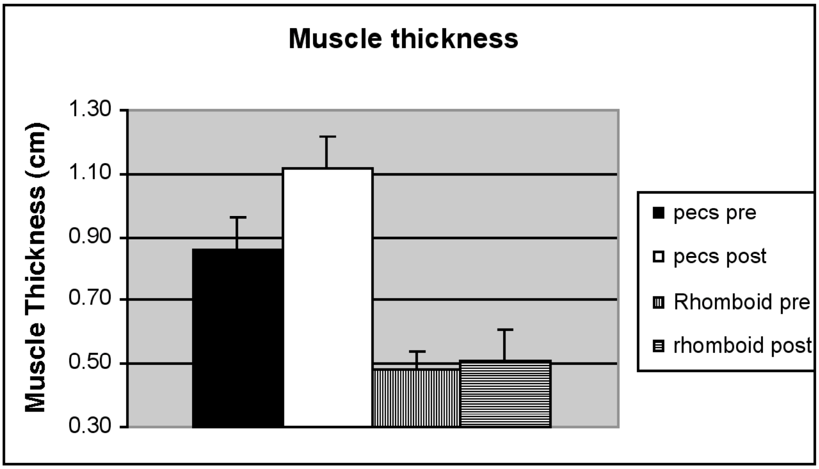
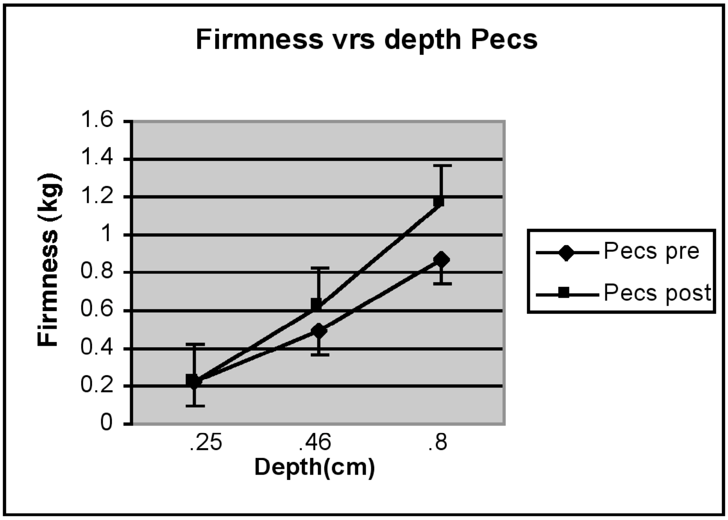


B

Figure 9. Muscle strength of the subjects before and after the training period (A) and muscle thickness by ultrasound before and after training for the pectoralis and rhomboid muscles (B).

uncommon to see strength increase within days along with an increase in muscle tone.[2] To increase strength further, some have been tempted to use anabolic steroids.[32] The nonsteroidal route involves isokinetic exercise, a type of exercise involving lifting weights slowly against heavy loads.[6-9] Strength training is especially important in people who get repetitive injuries. Poor upper body strength and balance, especially in the back and rotator cuff muscles can lead to their injuries.[15] With a high incidence of upper back injury in women,[33] upper body training is increasingly important. This is made more important



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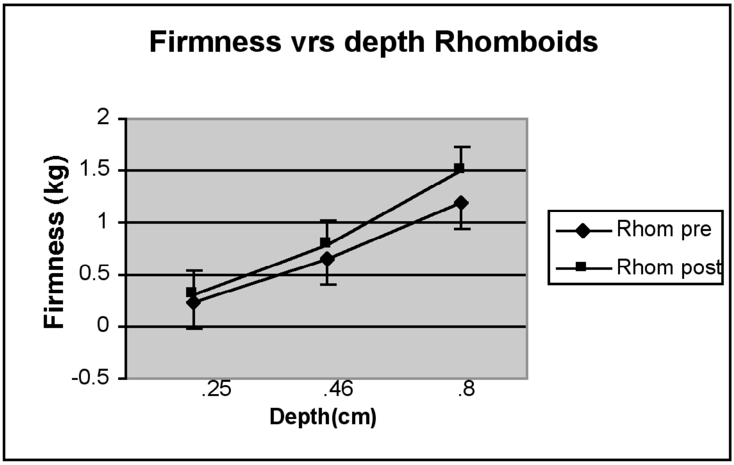

B

Figure 10. Firmness of the chest and back shown as compression force versus depth for the pectoralis (pecs) (A) and rhomboid muscles (B).

in women due to higher weight of the breast placing stress on the upper back and neck muscles.[34-36] This can be true even in power lifters.[37] When coupled with a higher incidence of osteoporosis in the spine in women (vertebral osteoporosis), this provides simply another predisposing factor to injuries.[38]

In the present investigation, exercise was only conducted for 5 minutes a day with 5 different exercises for a group of women involved in an exercise-testing program. The results of the experiment, however, show that even 5 minutes of exercise a day significantly increases upper body strength. This translated to an increase in chest firmness measurements, girth, and the thickness of the

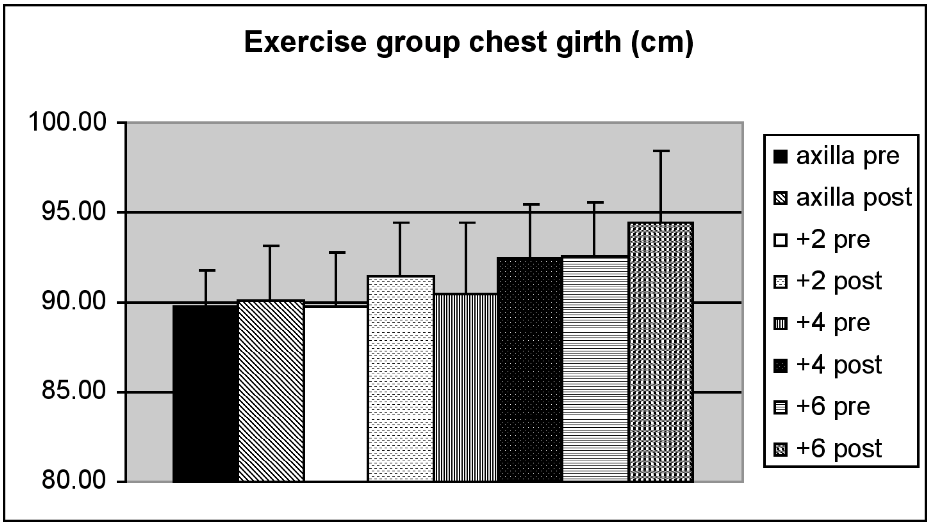

Figure 11. Chest girth before and after the 1-month period at the axilla and at 2, 4, and 6 cm below the axilla.

muscle layer above the pectoralis major and rhomboid muscles. Since imbalances around the rotator cuff have commonly been causal to injury,[15] this type of exercise should reduce injury incidence in individuals engaging in such an exercise program. The wide range of motion involving horizontal abduction, horizontal adduction, extension, and flexion associated with these exercises may also provide treatment for mobility at the shoulder. Mobility exercises to the shoulder have been shown to reduce osteoporosis.[18] Thus, for women there are positive benefits of increasing mobility at the shoulder[17] and other benefits of exercise including increases of muscle blood flow. Furthermore, exercise has been shown to reduce the risk of breast cancer.[21-24]

Another benefit of the exercise program examined here was in lifting the breast line. One common complaint of women is sagging breasts as they age. With large breasts, surgical intervention or wearing prosthetic appliances is common to alleviate pain and back injury.[39] In one study, Mizgala and Mackenzie[39] showed that in cases of 75 bilateral breast reductions, patients reported better posture and relief of lower back pain as the result of surgical intervention and reducing the size of their breasts. In all likelihood, strengthening the upper body muscles may have had a similar effect in compensating for the load of large breasts against the upper body as seen here. Another common complaint of women is neck pain as well as back pain, and shoulder grooving.[40] Exercise intervention was not tried in these studies to strengthen the neck, back, and chest muscles to compensate for the weight of sagging breasts and thus alleviate many of the symptoms. Christensen[16] found that exercise can be just as effective as surgery in reducing back pain as people age. It would be reasonable, then, that exercise intervention may also prevent many of the large number of surgeries performed on women with large breasts.

Finally, for women with small breasts, the increased firmness and contouring of the chest would have good benefits medically in terms of stability of

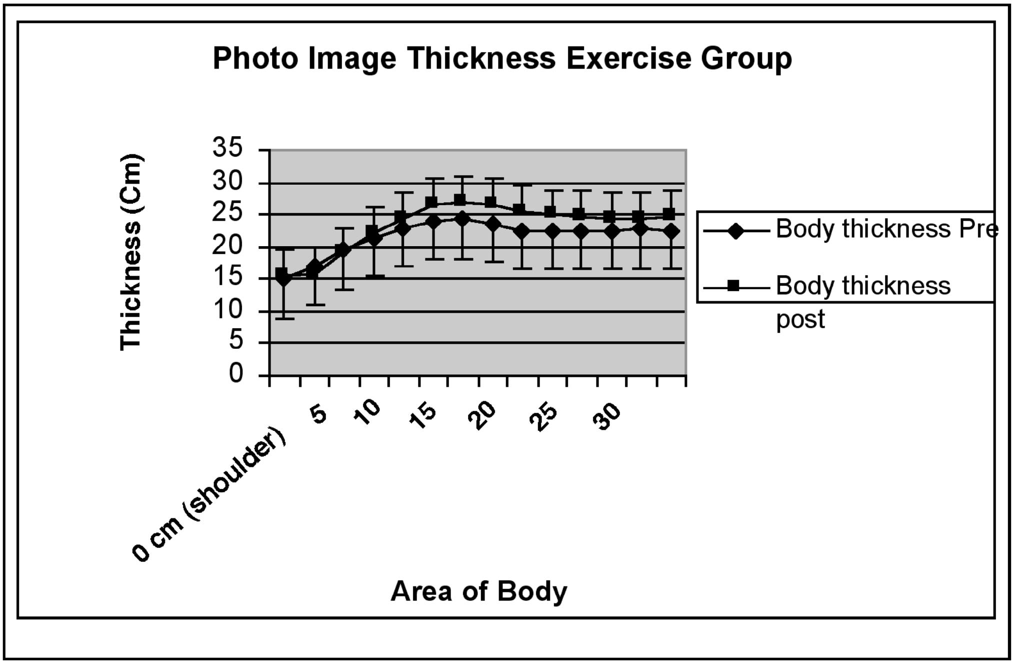

Figure 12. Thickness of body from photographic measurements before and after a 1-month exercise program.

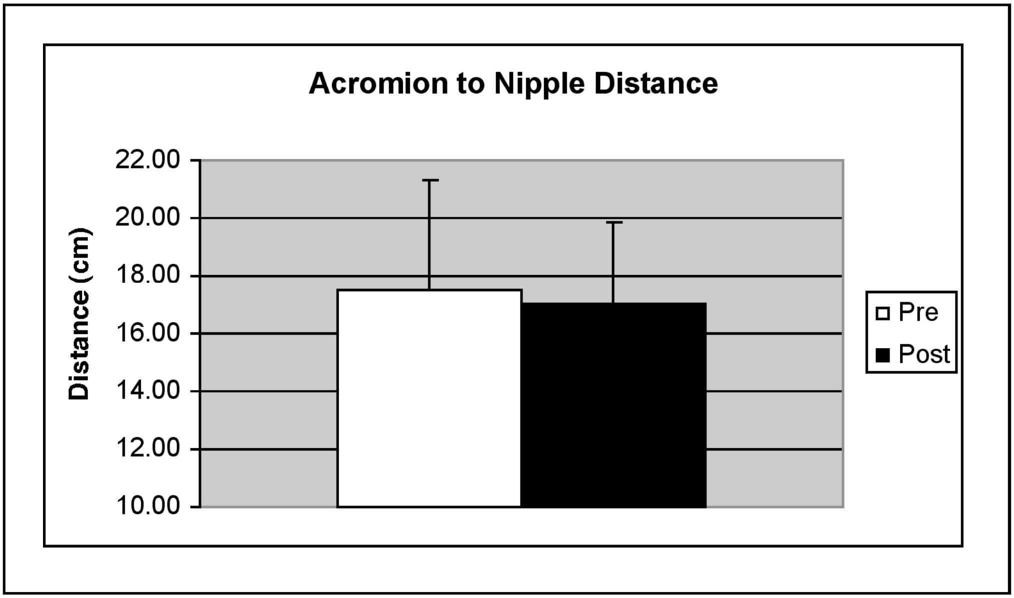

Figure 13. The change in distance from the shoulder to the breasts in the subjects before and after the exercise training.

the chest wall, and also psychologically, for a better outlook about their physique. Self-esteem becomes an important issue for women, and upper body exercise can dramatically improve self-esteem.[28]

In summary, given the small time commitment and effort of exercise at only 5 minutes per day, there are good benefits for such a device. Compliance for 30-minute exercise programs is poor due to the time commitment. Here, 5 minutes is a time that anyone can spare but with dramatic results in terms of esteem and lifestyle that are a testament to the benefit of the exercise. The results here show strength increased and muscle thickness increased, this caused girth and firmness to increase and the contours of the body on photo image to increase as well.

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