Muscle Strength Training and Weight Loss from a Combined Isometric Exercise and Dietary Program

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ABSTRACT

While many studies have examined the effect of diet and dynamic exercise on muscle strength and weight loss, none have examined a combined isometric exercise and diet program. Isometric exercise is unique in its ability to rapidly increase muscle strength and tone muscle faster than that seen for dynamic exercise. Ninety eight male and female subjects were randomly divided into 2 groups in a single-blind study. One group (controls) did not modify diet or exercise during the experimental period. The other group (exercise group) underwent a program of exercise and dietary modifacations. Compliance, muscle strength, body weight, girth, body fat, and blood chemistry were measured. The results showed that for all measurements taken, there was no difference in the control subjects over a 1-month period. However, muscle strength of the biceps, triceps, abdominals, hamstrings, quadriceps, and gluteus maximus muscles increased by 20.5, 15.4, 24.0, 12.5, 15.5, and 32.1%, respectively, for the exercise group. The average weight loss for the exercise group was 3.6 ± 1.2 kg, with a reduction in girth at the waist of 3.0 ± 1.0 cm after 2 weeks and 3.3 ± 1.1 cm after 4 weeks; at the hips 1.9 ± 0.9 cm after 2 weeks and 2.8 ± 1.1 cm after 4 weeks. After 2 weeks, for the thigh, the loss was 1.6 ± 0.8 cm and after 4 weeks the loss was 2.5 ± 1.1 cm at the mid thigh. Cholesterol and triglycerides showed significant reductions at 4 weeks for the exercise group. Compliance in the exercise group was 91.6% for the

Table 1. Initial Demographics of the Exercise and Control Groups.

	Age (years)	Height (cm)	Weight (kg)	Body Mass Index
Exercise Group	41.2 ± 12.6	165.4 ± 9.0	81.6 ± 16.4	29.8 ± 4.2
Control Group	38.9 ± 8.1	163.2 ± 9.1	77.4 ± 15.9	29.1 ± 3.9

All data is expressed as the group mean ± the standard deviation.

Table 2. Strength Measurements (lbs) of the Control Subjects at the Start, 1 Week, 2 Weeks, and 1 Month after the Initial Measurements

	Biceps	Triceps	Quadriceps	Hamstrings	Abdominal Flexors	Gluteus Maximus
Start	51.5	48.0	94.9	60.6	52.4	39.1
Week 1	53.5	48.8	104.5	60.7	54.7	39.6
Week 2	53.5	45.	97.5	60.9	52.8	36.9
Week 4	50.6	41.9	93.3	55.8	50.4	38.5
ANOVA	*P*>0.05	*P*>0.05	*P*>0.05	*P*>0.05	*P*>0.05	*P*>0.05

ANOVA=analysis of variance

exercise program and 89.5% for the diet.

In conclusion, this program worked well for both training and weight loss.

INTRODUCTION

Isometric exercise is commonly used for strength training.[1,2] It has been used for people with a variety of body types[3,4] and ages[1,2] and for both men and women.[5] For example, if isometric strength training is accomplished at different knee angles, the strength gain has been shown to be greater than that for dynamic exercise of the same muscle groups.[6,7] While there is some variation in the rate of increase in muscle strength with isometric exercise in older individuals and between men and women,[8-10] possibly due to age and maturation level,[11-14] it is still superior to dynamic exercise as a strength-training modality.[1,2,11,13] In addition to its strength-training properties, isometric exercise has been used to treat chronic neck and back pain.[15] An added benefit of isometric training is that it can lower blood pressure and heart rate at rest even days after the training session is over.[16]

Given the ability of isometric exercise to rapidly increase strength and muscle tone compared to dynamic exercise, it is surprising that it has never been used in combination with a dietary program for exercise and weight loss. Obesity is a significant problem in the world today.[17,18] While many dietary programs have been tested, the compliance of many programs is poor.[19,20] Part of this may be due to the fact that the improvements in exercise training are slow with dynamic exercise and time must be taken out of the day to exercise.[21] In addition, most diets are restrictive and/or require special foods, making them difficult to sustain.[21]

In the present investigation, isometric exercise was used for the exercise component of a diet and exercise program to allow subjects to see fast changes in strength, thereby encouraging them to keep exercising. Further, isometrics can be accomplished while sitting and working, making it a convenient form of exercise. To try to increase diet compliance, a dietary recommendation program was used. The hypothesis to be tested was that an isometric exercise program that allows rapid changes in muscle strength combined with a dietary recommendation program will cause significant weight loss and strength gains over a 1-month period and subjects will have good compliance.

Table 3. Systolic, Diastolic, Mean Blood Pressures; Heart Rate, Body Fat, and Lean Body Mass in the Control subjects

	Systolic Blood Pressure (mmHg)	Diastolic Blood Pressure (mmHg)	Mean Blood Pressure (mmHg)	Heart Rate (beats per minute)	Body Fat by Impedance (% of body weight)	Lean Body Bass (kg)
Start	117.9	74.6	88.9	71.1	30.3	53.9
Week 1	119.4	73.6	86.7	68.8	30.5	54.6
Week 2	116.6	74.7	88.6	73.4	31.6	53.5
Week 4	119.2	73.2	81.3	70.4	31.1	53.1
ANOVA	*P*>0.05	*P*>0.05	*P*>0.05	*P*>0.05	*P*>0.05	*P*>0.05

ANOVA=analysis of variance

Table 4. Girth Measurements (cm) in the Control Group

	Waist	Waist +2.5 cm	Waist -2.5 cm	Hips	Thigh
Start	87.9	87.1	90.8	104.0	56.3
Week 1	88.9	89.2	91.7	104.2	56.2
Week 2	88.6	88.3	91.6	104.1	56.1
Week 4	87.5	86.9	91.2	104.2	55.4
ANOVA	*P*>0.05	*P*>0.05	*P*>0.05	*P*>0.05	*P*>0.05

ANOVA=analysis of variance

SUBJECTS

The experimental subject group consisted of 15 males and 33 females ranging in age from 22 to 61 years. The control group consisted of 20 males and 30 females aged 19 to 55 years. For the control group, only measurements were taken. The subjects responded to an advertisement on the Internet at Azusa Pacific University. Inclusion criteria included a body mass index (BMI) of greater than 25 but less than 35. Exclusion criteria included the taking of diet pills, weight that was not stable for at least 3 months prior to the study, diabetes, or cardiovascular disease. Both groups were instructed not to change exercise or diet patterns during the experimental period except for the diet and exercise pattern given to the exercise group. All protocols and procedures were approved by the Institutional Review Board of the Azusa Pacific University and all subjects signed a statement of informed consent. The general characteristic of the subjects at the beginning for the study is shown in Table 1. There was no significant difference between the groups with regard to sex, height, age, and weight ($P>0.05$).

METHODS

Isometric Exercise

Isometric exercise was accomplished in 4 sets of exercises. Subjects simultaneously contracted agonist and antagonist pairs of muscles for 25 seconds and then rested for 5 seconds. The exercise included 1) contracting the biceps triceps groups while stabilizing the core by contracting the abdominal-lower back muscle groups, 2) contracting the biceps triceps and core muscles with the arms extended behind the body, 3) contracting the quadriceps hamstring groups and contracting the hip flexor extensors (gluteus maximus) with the body erect, and 4) flexing the facial muscles. For exercises 1-3, all contractions were sustained for 25 seconds and 4 repetitions were done each day. Thus for 3 exercise areas, a total of 12 repetitions were done each

Table 5. Blood Values in the Control Group

	Cholesterol (mg/dL)	Glucose (mg/dL)	High-Density Lipoprotein (mg/dL)	Low-Density Lipoprotein (mg/dL)	Triglycerides (mg/dL)
Start	207.3	95.6	73.8	130.9	189.3
End	203.3	96.4	71.4	127.0	193.2
t-test	*P*>0.05	*P*>0.05	*P*>0.05	*P*>0.05	*P*>0.05

Table 6. Systolic, Diastolic, Mean Blood Pressures; Heart Rate; Body Fat; and Lean Body Mass in the Exercise Group

	Systolic Blood Pressure (mmHg)	Diastolic Blood Pressure (mmHg)	Mean Blood Pressure (mmHg)	Heart Rate (beats per minute)	Body Fat by Impedance (% of body weight)	Lean Body Mass (kg)
Start	125.7	78.9	94.3	77.1	33.1	54.6
Week 1	126.6	79.6	95.1	77.3	32.2	54.3
Week 2	125.8	79.6	94.9	75.1	31.6	53.9
Week 4	121.2	75.2	90.0	70.5	30.6	54.2
ANOVA	*P*<0.05	*P*<0.05	*P*<0.05	*P*>0.05	*P*<0.01	*P*>0.05

ANOVA=analysis of variance

day. The facial exercise was sustained for 50 seconds with only 1 repetition performed each day. The total exercise time was 7 minutes each day. A videotape with these exercises was followed for the studies to provide a consistent regimen.

Measurements

Strength was measured with a strain gauge. The device consists of a handgrip strength measuring device[2] and measured compression force. Subjects were asked to flex the appropriate muscle groups and strength was recorded through a nylon strap connected to the device. Force was measured on 3 occasions with 1 minute allowed between each measurement.

Blood pressure was measured by auscultation of the left arm. An automatic blood pressure cuff was used on the wrist (Omron HEM-621; Omron Healthcare, Inc., Bannockburn, Illinois). Heart rate was determined by counting the radial pulse over a 15-second period and multiplying by 4.

Body fat content was measured by an impedance plethysmograph (RJL Systems, Clinton Township, Michigan).

Girth measurements were made by a measuring tape with a tensionometer that applied 3 grams of force during the measurements. The same person made all of the measurements. Girth was measured at the umbilicus and ± 1 inch (2.5 cm) above and below the umbilicus, mid thigh and around the hips.

A 12-hour fasting venous blood sample was taken at the beginning and end of the studies to measure glucose, cholesterol, low-density lipoprotein (LDL), high-density lipoprotein (HDL), and triglycerides.

Recommended Diet and Exercise Program

A booklet and a video were given to each subject and an exercise program was to be followed along with lifestyle and behavior recommendations. The suggestions were:

1. Record body weight and girth and record goals. Girth was to be measured on the upper arm, thigh, waist, and hips and recorded on a graph.
2. Look up the calories their body need-

Table 7. Blood Values in the Experimental Group

	Cholesterol (mg/dL)	Glucose (mg/dL)	High-Density Lipoprotein (mg/dL)	Low-Density Lipoprotein (mg/dL)
Start	232.6	93.0	61.3	145.3
End	205.5	92.1	64.8	130.4
ANOVA	$P<0.01$	$P>0.05$	$P<0.05$	$P<0.01$

ANOVA=analysis of variance

ed. They were asked to avoid high-calorie foods and choose healthy foods.
3. Eat high-volume foods such as beets, carrots, and asparagus which fill them up with low-density calories.
4. Drink six 8-ounce glasses of water daily while minimizing calorie-laden drinks such as soda.
5. Reduce temptation by keeping high-calorie foods out of sight.
6. Think of small things to do that increase body movement during the day.
7. Get 1 to 3 people to be buddies to help stick to the program.

All seven recommendations were to be followed by each subject.

Compliance
A scale was used to assess compliance. A questionnaire was given to each of the subjects in the exercise group to log their dietary and exercise compliance daily as follows:

Exercise
0= did not exercise at all
1= exercised 1 day of the 6 required
2= exercised 2 days of the 6 required
3= exercised 3 days of the 6 required
4= exercised 4 days of the 6 required
5= exercised 5 days of the 6 required
6= exercised all 6 days
7= exercised all 7 days

Diet
0= did not follow the diet
1= cheated 6 days
2= cheated 5 days
3= cheated 4 days
4= cheated 3 days
5= cheated 2 days
6= cheated 1 days
7= did not cheat

For the control group, subjects were asked to log any change in diet or exercise from their normal pattern.

PROCEDURES

The study protocol was a single-blinded randomized design. The technicians taking measurements did not know which group the subjects were in. All subjects first entered the lab where blood pressure, heart rate, girth, strength, weight, height, and body fat were assessed. A blood sample was also taken. This was accomplished on all subjects at the onset, at 1 week, 2 weeks, and 30 days into the study. The control group only had the measurements made while the experimental group engaged in isometric exercise 7 days per week for 1 month as described under methods and followed the 7 lifestyle-behavioral recommendations. The muscles to be examined were the biceps, triceps, hamstrings, quadriceps, abdominal flexors, and gluteus maximus muscles.

Data Analysis
Data analysis involved the calculation of

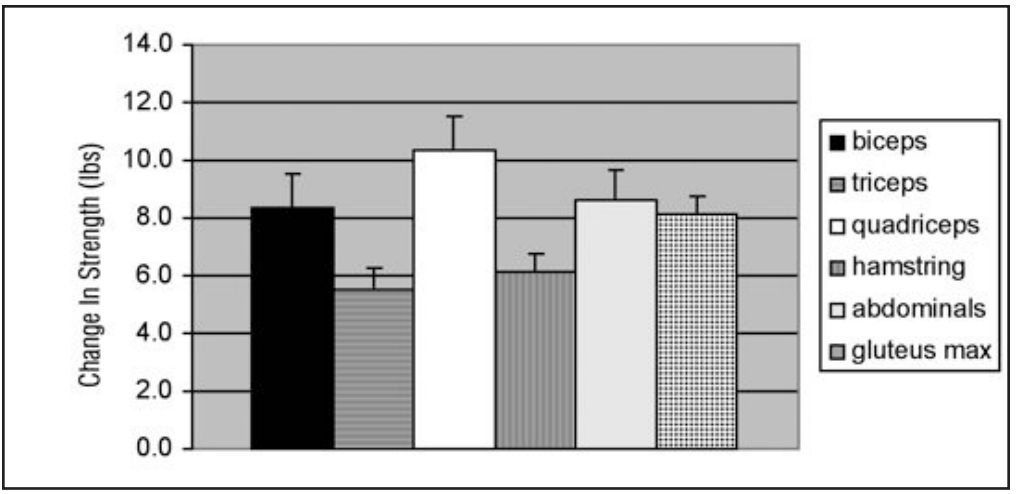

Figure 1. Change in strength in the experimental group when comparing the strength at the beginning to the strength recorded at the end of the exercise training period.

the means, standard deviations, *t*-tests, and 2-tailed analysis of variance (ANOVA). The level of significance was $P<0.05$.

RESULTS

Control Subjects

The strength of the control subjects for the biceps, triceps, quadriceps, hamstrings, abdominal flexors, and gluteus maximus muscles was measured at the start, the first week, second week, and after 30 days (Table 2). There was no statistical difference in the strength of any muscle group at any point in the study ($P>0.05$). The body weight of the control group, which started at 77.4 ± 15.9 kg, was 77.0 ± 16.6 kg at the end of the 4-week period ($P>0.05$). As shown in Table 3, for the control subjects, body fat, measured by impedance plethysmography, averaged 30.3 ± 9.9% of the body weight at the start of the study, while at the end of 4-weeks the subjects had an average of 31.1 ± 9.9% body fat ($P>0.05$). Lean body mass, which started at 53.9 ± 14.4 kg was, at the end of 4 weeks, 53.1 ± 14.9 kg. There was also no statistical difference in the girth (Table 4) at the waist, 2.5 cm above the waist, 2.5 cm below the waist, at the hips, or thigh for any of the measuring periods ($P>0.05$). Systolic blood pressure, diastolic blood pressure, mean blood pressure, and heart rate were not statistically different throughout the 4-week period ($P>0.05$). The same was true for blood cholesterol, glucose, HDL, LDL, and triglycerides ($P>0.05$) (Table 5). All subjects reported no change in physical activity or diet during the 1-month period.

Experimental subjects

For the exercise group, muscle strength increased significantly in all muscle groups examined at each test period (ANOVA $P<0.01$). For the biceps over the 1-month period, strength increased from 18.4 ± 5.3 to 22.2 ± 6.0 kg while the triceps strength increased from 16.2 ± 4.3 to 18.7 ± 7.0 kg. For the quadriceps, hamstrings, abdominal flexors, and gluteus maximus muscles, strength increased from 28.2 ± 7.5 to 32.9 ± 9.9; 22.2 ± 5.9 to 25.0 ±6.6; 16.3 ±5.9 to 20.2 ± 5.6; and 11.5 ± 3.4 to 15.2 ± 3.9 kg, respectively. The change in muscle strength from beginning to end of the study averaged 3.6 kg (Figure 1).

Body weight was statistically reduced in the experimental group. Body weight, which started at 81.6 ± 16.4 kg, was

reduced to an average of 78.8 ± 15.3 kg after 2 weeks, and after 4 weeks was reduced to a final value of 78.0 ± 15.3 kg. Body fat was statistically reduced by 1.52 ± 1.1% after 2 weeks and 2.47 ± 1.3% after 4 weeks.

Lean body mass, which started at 54.6 ± 14.7 kg, was 53.9 ± 14.0 kg after week 2 and 54.2 ± 14.0 kg after week 4. There was no significant change in lean body mass at any time in the study. As well as body weight decreasing and body fat decreasing, in the experimental group, girth also statistically decreased over the 1-month period. Girth started at 94.3 ± 12.2 cm for the waist, 92.8 ± 13.2 cm for the waist +2.5 cm, 95.3 ± 11.7 cm for the waist -2.5 cm, 108.3 ± 8.8 cm for the hips, and 57.9 ± 5.9 cm for the thigh. This was reduced to 92.0 ± 12.0, 89.9 ± 13.9, 91.5 ± 11.5, 106.9 ± 8, and 56.4 ± 5.8 cm, respectively, after 2 weeks. This was a loss of 2.3, 2.9, 3.9, 1.4, and 1.6 cm at the waist, waist +2.5 cm, waist -2.5 cm, hips, and thigh, respectively.

Using body weight and percent fat data, the average fat loss was 2.1 kg over the 2 week period or a loss of body weight with 75% of the weight loss being fat. After 1 month, girths were 91.3 ± 12.4, 88.0 ± 13.7, 92.5 ± 12.5, 105.4 ± 7.2, 55.4 ± 5.6 cm at the waist, waist +2.5 cm, waist -2.5 cm, hips, and thigh, respectively. The average loss for the 4-week period was 3.3 cm at the waist. This was a respective loss of 3.1, 3.9, 2.8, 2.8, and 2.5 cm. Using body weight and percent fat data, the average fat loss was 3.1 kg over the 4-week period or a loss of body weight with 88% of the weight loss being fat.

Blood pressure and heart rate were all reduced significantly (Table 6). HDL, LDL, total cholesterol, and triglycerides were also reduced significantly over the 1-month period (Table 7). There was no significant difference in glucose (P>0.05).

Calculating compliance as a percent of the total possible compliance, compliance in the exercise group was 91.6 ± 6.2% for the exercise program and 89.5 ± 7.1% for the diet.

DISCUSSION

Isometric exercise has been used as a means of strength training of muscle.[6,7,22] The reason it seems to increase strength so quickly is that, during isometric exercise, intramuscular pressure occludes much of the circulation to the muscle. This anoxia, in turn, stimulates the synthesis of actin and myosin.[6,8] As a result of this type of training, there is also generally a reduction in resting blood pressure and heart rate.[23]

In the present investigation, it is not surprising that with isometric training, there was a marked increase in muscle strength. Thus, the isometric exercise program worked well in terms of increasing muscle strength. It is significant that there was a 20% increase in muscle strength with only 7 minutes of work each day.

But the program, while increasing muscle strength was equally matched by the benefits of weight and girth loss. The loss in girth after 2 weeks, for the average person at the waist was 3.0 cm which was equivalent to one pant or dress size. After 4 weeks the loss increased to 3.3 cm. The weight loss for some subjects in the first 2 weeks was as high as 8.4 kg while after 4 weeks some subjects lost as much as 10.1 kg in body weight. Almost 25% of the subjects lost more than 4 kg in the first 2 weeks. More than 10% of the subjects lost 5 cm or more at the waist. The circumference loss of several of the participants was 5 cm or more in the first 2 weeks.

The dietary recommendations, unlike others where a rigid diet is followed, involved recommendations for lifestyle and behavioral improvements and reduced consumption of high-calorie foods. This program was much easier

(better compliance) than a conventional restrictive diet program. Subjects here showed significant weight loss and reductions in blood cholesterol and glucose and LDL cholesterol showing how effective the overall program was.

The combined exercise program described in this paper increases fitness. This regimen is practical and can be performed virtually anywhere with good compliance, making it easier for people with severe time constraints to engage in exercise. The observed reductions in both average total cholesterol from 232 mg/dL to 202 mg/dL and blood pressure would be expected to beneficially impact risk for cardiovascular disease and its various sequelae.[24,25]

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