Contrasting Effects of Resistance and Aerobic Training on Body Composition and Metabolism After Diet-Induced Weight Loss

Douglas L. Ballor, Jean R. Harvey-Berino, Philip A. Ades, Janet Cryan, and Jorge Calles-Escandon

This study examined whether exercise training facilitates maintenance of body weight at reduced levels following weight loss by attenuating weight loss–induced reductions in resting metabolism and fat oxidation. The effects of 12 weeks (three times per week) of either aerobic or weight training exercise on body weight, body composition, and energy metabolism during rest and following a meal in 18 older (mean ± SE, 61 ± 1 years; range, 56 to 70) subjects who had recently lost a mean of 9 ± 1 kg were studied. During the exercise training period, the aerobic training group (five women, four men) had a significant ($P < .05$) reduction in body weight (−2.5 ± 0.6 kg) as compared with the weight training group (five women, four men) (0.4 ± 0.9 kg). Eight of nine aerobic training subjects lost additional weight, while six of nine weight training subjects gained weight. Neither type of training reversed the depressions in resting metabolism or fat oxidation rates (ie, resting or postprandial) that had occurred as a consequence of the prior weight loss. Thus, alterations in resting metabolism or fat oxidation (resting or postprandial) do not appear to be the mechanism(s) by which exercise training facilitates maintenance of diet-induced weight loss.

ALTHOUGH it is relatively easy to lose weight via dietary restriction, long-term maintenance of body weight at reduced levels is problematic.[1] Many mechanisms have been proposed to explain weight recidivism, including those with physiological, sociological, and psychological origins.[2] However, to maintain body weight at reduced levels, one must, as Flatt[3] has noted, be in both energy and fat balance (ie, intake = expenditure), and therefore potential mechanisms must affect either intake or expenditure. Consistent with this, dietary restriction and subsequent weight loss has been shown to reduce rates of resting metabolism and fat oxidation.

For example, we recently completed a weight loss program in which 18 older subjects (aged 61 ± 1 years) lost a mean of 9 ± 1 kg over 11 weeks (see preceding report). Following weight loss, the subjects' resting metabolic rate and 5-hour postprandial fat metabolism were reduced by 15% and 40%, respectively. If these subjects do not reduce energy and fat intake from that present at baseline, weight regain would appear inevitable.

Regular exercise is strongly associated with maintenance of weight at reduced levels,[4] although the mechanism(s) by which it does so are not clear. However, there are many potential mechanisms by which exercise training could facilitate maintenance of body weight at reduced levels, including increased daily energy expenditure, reduced appetite, elevated resting metabolic rate, increased fat-free mass, enhanced thermic effect of a meal, postexercise oxygen uptake, greater rates of fat mobilization and utilization, as well as an enhanced sense of self-efficacy and well-being.[2]

The primary purpose of this study was to examine whether the mechanism by which exercise training facilitates maintenance of body weight at reduced levels is by attenuating the reductions in resting metabolism, resting fat oxidation, and fat oxidation during the postmeal period that often accompany weight loss. A secondary purpose was to compare prospectively the maintenance of weight loss and changes in body composition among subjects regularly participating in either aerobic or weight training exercise.

SUBJECTS AND METHODS

Overview

Following an 11-week weight loss program in which older (aged 61 ± 1 years; range, 56 to 70) obese (body fat, 45% ± 2%) subjects reduced their body weight by a mean of 9 ± 1 kg, 18 of these subjects were randomly assigned by gender to either a 12-week aerobic training (four men, five women) or weight training (four men, five women) exercise regimen. All subjects exercised in the same room at the same time and were supervised by the same exercise leaders. At the start of the study the two groups were similar, with no statistically significant between-group differences for body weight, percent fat, fat-free mass, or fat mass. Before and after completion of the exercise training program, subjects underwent the following evaluations during a 2-day stay at the University of Vermont Clinical Research Center. On day 1, resting metabolic rate and body composition were assessed. On day 2, resting metabolic rate and the effect of a high-fat meal on postprandial metabolism were studied. Three to 7 days before admission to the Clinical Research Center, subjects underwent one-repetition maximum-strength and peak oxygen consumption tests. All subjects gave written voluntary consent via an informed-consent statement previously approved by the University of Vermont Committee on Human Research.

Subjects

Study selection criteria required that the subjects be between ages 55 and 70 years, have a body mass index (before weight loss) of greater than 32 kg/m^2, have no signs, symptoms, or history of heart disease, be nondiabetic and a nonsmoker, and have a resting blood pressure less than 160/90 mm Hg, an absence of any prescription or over-the-counter drugs that could alter metabolism, and no symptoms that would preclude safe participation in an exercise training program. Subjects were solicited via advertisements in local media.

From Sims Obesity Research Center, University of Vermont, Burlington, VT.
Submitted December 23, 1994; accepted June 28, 1995.
Supported in part by General Clinical Research Center Grant No. NIH RR-109 and National Institutes of Health Grant No. NIDDKD 5 P30 DK46188-02.
Reprints not available.

0026-0495/96/4502-0008$03.00/0

Dietary Intake

During the weight loss program, subjects were given formal instruction as to what represents a "healthy" diet and strategies for identifying and dealing with problem situations/foods, etc. During the exercise training period, subjects were allowed to eat ad libitum foods of their choice. No formal dietary counseling was given during this 12-week period. However, it should be noted that the subjects met three times weekly for exercise training with subjects with whom they had undergone a weight loss regimen. Furthermore, subjects knew that they were participating in an experiment that examined the effects of exercise training on weight recidivism. Thus, the subjects' food selection during this period and the weight that they maintained may have been affected by their continued participation in the present study.

Weight Training Program

The weight training regimen consisted of 3 days per week of three sets of eight repetitions of the following exercises (primary muscles exercised in parentheses) using Universal Gym (Cedar Rapids, IA) apparatus: leg extension (quadriceps), leg curl (hamstrings), arm extension (triceps), arm curl (biceps), lateral pulldown (latissimus dorsi and biceps), bench press (pectoralis major and triceps), and squat (gluteals and quadriceps). The subjects started exercising at a resistance that represented 50% of their one-repetition maximum strength. The resistance was progressively increased until, by the beginning of the ninth week, subjects were exercising at 80% of their one-repetition maximum strength. Every 3 weeks, subjects' one-repetition maximums were retested and training loads adjusted as required.

Aerobic Training Program

The aerobic training subjects walked 3 days per week on motorized treadmills at speeds and grades intended to elicit an oxygen uptake of approximately 50% of maximum. Initially, they walked 20 minutes per session, with the duration per exercise session increasing by 10 minutes per week until the subjects were walking 60 minutes per session (week 5). Subjects were allowed to adjust the speed and grade to their individual preference as long as they did not go below 50% of peak oxygen uptake (ie, some exercised at slightly higher work rates). Heart rates for the subjects were also taken at the midpoint of each exercise session.

Resting Metabolic Rate

Resting metabolic rate was determined approximately 12 hours after a standard meal while the subjects reclined in a supine position underneath a ventilated hood. Resting metabolic rates were determined on 2 successive days and averaged. Subjects had last exercised on the day before admission to the Clinical Research Center, and thus 36 to 60 hours had elapsed between the last exercise training session and the two resting metabolic rate determinations. Energy expenditure was estimated via the Weir equation.[5] In this procedure, urinary nitrogen excretion is used to calculate protein-based contributions to oxygen uptake and carbon dioxide production. These are subtracted from the total oxygen and carbon dioxide values, and the nonprotein respiratory exchange ratio is then calculated. From this, the percentage of energy derived from fat and carbohydrate sources and the energy value associated with a given quantity of oxygen can be determined. The intraclass correlation and the coefficient of variation for the determination of energy expenditure in our laboratory have been shown to be .90 and 4.3%, respectively.[6]

Postprandial Metabolism

Postprandial metabolism following a high-fat meal (45% carbohydrate, 40% fat, and 15% protein) was studied in each subject. Upon awakening, each subject's resting metabolic rate was measured as described earlier. A liquid meal (15 kcal/kg pre–weight loss fat-free mass) was then quickly ingested. The metabolism of the subject was then monitored (as described later) for the next 5 hours. For the first 60 minutes, the subject reclined under the ventilated hood and then alternated 30-minute periods of resting supine outside of and underneath the ventilated hood. The first 10 minutes of each assessment period were excluded (to allow for reequilibration), and the mean was calculated for the remaining samples. Approximately 60 hours had elapsed between the last time these subjects exercised and the start of this test. Energy expenditure was calculated as reported for resting metabolic rate. The thermic effect of the meal is the difference between average postprandial and average resting rates of energy expenditure. The same size high-fat meal was given to each respective subject at the beginning and end of the study.

Body Composition

Underwater weighing with simultaneous corrections for residual volume (helium dilution) was used to determine body density. The Siri equation[7] was then used to estimate percent fat.

One-Repetition Maximums

One-repetition maximums were measured, using Universal Gym apparatus, under formal testing conditions for the following exercises: bench press, leg extension, and leg curl. Following instruction as to the proper way to complete the exercise, subjects were asked to lift progressively heavier weights until they reached a weight they were not able to lift successfully. Weights to be lifted were selected such that each subject reached their maximum capacity in four to six lifts, with subjects being given adequate rest between trials.

Peak Oxygen Uptake

Peak oxygen uptake was assessed on a motorized treadmill via a modified Balke walking protocol using a Sensormedics MMC (Yorbalinda, CA) metabolic cart. Basically, the speed and grade on the treadmill were increased until the subjects were no longer able to continue.

Statistics

Paired t tests[8] were performed to compare post–weight loss and post–exercise training (follow-up) conditions within a respective (ie, aerobic or weight training exercise) group. Independent t tests[8] were performed for the change scores (follow-up minus post–weight loss) to determine if the effect of the training protocols differed between groups. The means were accepted as being statistically different from each other if the P value was less than .05. Results are reported as the mean ± SE.

RESULTS

Table 1 lists physical characteristics of the subjects at the conclusion of their weight loss program (postdiet) and at the end of the 12-week exercise training period (follow-up). As noted earlier, aerobic training and weight training subjects did not differ with respect to physical characteristics at the start of the exercise training program. This can be seen by comparing the postdiet scores of the two groups. As

Table 1. Physical Characteristics of the Subjects (mean ± SE)

Variable	WT			AT		
	Postdiet	Follow-up	Change	Postdiet	Follow-up	Change
Weight (kg)	84.6 ± 4.0	85.0 ± 4.4	0.4 ± 0.9*	84.2 ± 3.3	81.7 ± 3.2*	−2.5 ± 0.6*
Percent fat (%)	41.2 ± 2.7	39.6 ± 2.4	−1.6 ± 0.7	41.7 ± 2.3	40.6 ± 2.5	−1.1 ± 0.4
Fat-free mass (kg)	50.4 ± 4.4	51.9 ± 4.4	1.5 ± 0.8*	49.4 ± 3.3	48.8 ± 3.2	−0.6 ± 0.4*
Fat mass (kg)	34.2 ± 1.6	33.0 ± 1.6	−1.2 ± 0.7	34.8 ± 1.9	33.0 ± 2.1*	−1.8 ± 0.8
Waist to hip ratio	0.87 ± 0.03	0.86 ± 0.03	−0.01 ± 0.01	0.86 ± 0.03	0.87 ± 0.02	0.01 ± 0.03
Peak oxygen uptake (mL/kg/min)	23.4 ± 1.2	24.8 ± 1.4	1.4 ± 0.9	23.9 ± 1.6	26.8 ± 1.1*	2.9 ± 0.9
Bench press 1RM (kg)	34.9 ± 4.3	38.1 ± 4.0*	3.2 ± 1.0	34.7 ± 6.3	37.0 ± 4.4	2.3 ± 1.1
Leg extension 1RM (kg)	29.0 ± 3.3	37.2 ± 3.8*	8.2 ± 2.8	34.1 ± 4.8	36.6 ± 4.4	2.5 ± 1.6
Leg curl (kg)	16.7 ± 2.1	19.2 ± 2.0*	2.5 ± 0.5	15.2 ± 2.7	17.8 ± 2.9	2.6 ± 1.3

NOTE. *$P < .05$: When the asterisk is in the follow-up column, postdiet mean is significantly different from respective follow-up mean; when it is in the change column, AT change is significantly different from WT change. Postdiet represents subject data measured following completion of a weight loss program and while weight-stable. Follow-up was measured at completion of the exercise training program. Change equals follow-up minus postdiet score.

Abbreviations: AT, aerobic training; WT, weight training; 1RM, one-repetition maximum.

expected, the weight training program significantly ($P < .05$) increased one-repetition strength for the bench press (+9%), leg extension (+28%), and leg curl (+15%), whereas mean values for the aerobic training group remained unchanged. In contrast, peak oxygen uptake for the aerobic training group increased ($P < .05$) by approximately 12%, whereas that of the weight training group remained unchanged. The mean heart rate (taken at the midpoint of the exercise sessions) for the aerobic training group was 125 ± 1 beats per min (78% of maximum).

Body weight for the weight training group (change, 0.4 ± 0.9 kg) remained unchanged ($P > .05$) over the 12-week period, while that of the aerobic training group decreased ($P < .05$) by 2.5 ± 0.6 kg (3%). Eight of nine aerobic training subjects lost weight, while six of nine weight training subjects gained weight. The change for the aerobic training group was also statistically different ($P < .05$) from that for the weight training group. There was a tendency for percent body fat in the weight training group to decrease ($P = .059$), while that of the aerobic training group remained unchanged. Fat-free mass for the weight training group also tended to increase ($P = .071$), while that of the aerobic training group remained unchanged. The weight training group's fat-free mass change (1.5 ± 0.8) was significantly different ($P < .05$) from that of the aerobic training group (−0.6 ± 0.4). Fat mass for the aerobic training group was significantly ($P < .05$) reduced (5%), while that of the weight training group remained unchanged. Figure 1 depicts changes in body weight, fat mass, and fat-free mass that occurred as a result of the training.

Table 2 lists resting metabolic rate data. The weight loss program (see preceding report) had resulted in a reduction in resting metabolic rate of approximately 260 kcal/d, as well as a decrease in the rate of fat oxidation. Weight training exercise tended ($P = .068$) to increase resting metabolic rate, while that of the aerobic training group remained unchanged. For the weight training group, protein oxidation increased (36%) significantly ($P < .05$) while the percentage of resting metabolism from fat sources decreased (from 48% to 30%) significantly ($P < .05$), with a tendency for reductions in the rate of fat oxidation (−31%, $P = .058$). In contrast, there were no changes in resting metabolism as a result of aerobic exercise training.

Table 3 reports the effects of a high-fat (40%) meal on postprandial metabolism during the 5-hour period following ingestion of the meal. With weight loss (see preceding report), these subjects experienced a dramatic decrease ($P < .05$) in the percentage of energy derived from fat sources (from 38% to 26%), as well as reductions in total energy expenditure (−0.16 kcal/min) and fat substrate oxidation (−0.22 kcal/min). The thermic effect, or the increase in energy expenditure above rest, of the meal

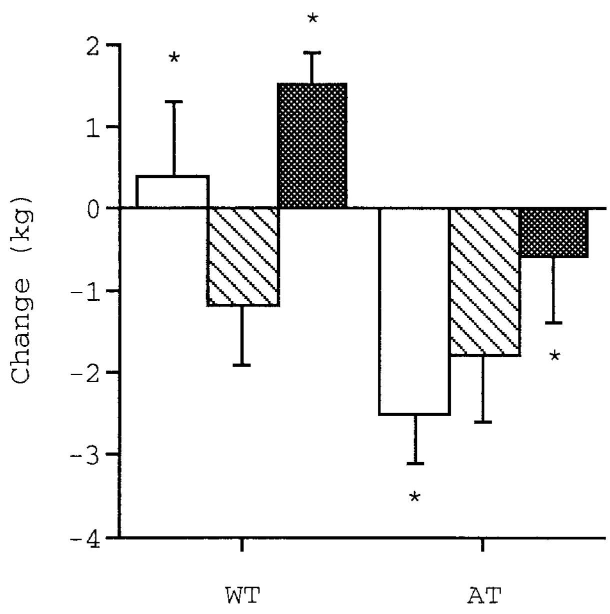

Fig 1. Changes in body weight (□), fat mass (▧), and fat-free mass (▩) following 12 weeks of exercise training (mean ± SE). AT, aerobic training group; WT, weight training group. *AT change significantly different from WT change, $P < .05$. See Table 1 for within-group changes.

Table 2. Resting Metabolic Rate Determinations (mean ± SEM)

Variable	WT Postdiet	WT Follow-up	WT Change	AT Postdiet	AT Follow-up	AT Change
Respiratory exchange ratio	0.84 ± 0.01	0.88 ± 0.02	0.04 ± 0.02	0.85 ± 0.02	0.88 ± 0.01	0.03 ± 0.02
RMR						
kcal/24 h	1,577 ± 89	1,656 ± 107	79 ± 37	1,455 ± 80	1,443 ± 81	−12 ± 41
cal/kg	12.9 ± 0.3	13.2 ± 0.4	0.3 ± 0.5	12.0 ± 0.3	12.3 ± 0.3	0.3 ± 0.3
kcal/min	1.10 ± 0.06	1.15 ± 0.07	0.05 ± 0.04	1.00 ± 0.05	1.01 ± 0.06	0.01 ± 0.03
Fat (kcal/min)	0.52 ± 0.05	0.37 ± 0.08	−0.15 ± 0.07	0.43 ± 0.06	0.33 ± 0.04	−0.10 ± 0.07
Carbohydrate (kcal/min)	0.44 ± 0.05	0.59 ± 0.06	0.15 ± 0.07	0.40 ± 0.05	0.50 ± 0.04	0.10 ± 0.05
Protein (kcal/min)	0.14 ± 0.02	0.19 ± 0.02*	0.05 ± 0.03	0.17 ± 0.02	0.18 ± 0.01	0.01 ± 0.02
Percent kcal as fat (%)	47.4 ± 3.9	30.4 ± 6.5*	−17.0 ± 6.6	42.2 ± 4.7	32.5 ± 3.2	−9.7 ± 5.5

NOTE. See Table 1 for abbreviations and definitions.

remained unaffected by weight loss. During the exercise training period, weight training exercise resulted in a statistically significant increase ($P < .05$) in total energy expenditure (+8%) during the postmeal period, and this was statistically different ($P < .05$) from that of the aerobic training group, whose total energy expenditure remained unchanged. All other variables remained unchanged for the weight training group. The aerobic training group had a statistically significant ($P < .05$) increase in protein oxidation (+36%) and a tendency toward reductions in the percentage of energy derived from fat sources (24.5% to 12.8%, $P = .06$) and the rate of fat oxidation (−52%, $P = .058$).

DISCUSSION

Flatt[3] has theorized that for one to be weight-stable, one must be in both energy and fat balance (ie, intake must equal expenditure). Thus, body weight will increase whenever total energy or fat intakes exceed the rate at which they are expended. The relationship between weight maintenance and fat balance is due to the inability of one's body to increase rates of fat oxidation during times of high-fat intake.[9] In addition, Schutz et al[10] have presented evidence that a linkage exists between daily rates of fat oxidation and body weight, with resting rates of fat oxidation decreasing by 2 g/d for every kilogram of decrease in body weight.

Since weight loss in these subjects resulted in reductions in resting metabolic rate (−15%), percentage of fat used to supply energy following a meal (from 38% to 26%), and rate of fat oxidation following a meal (−41%), the energy and fat balance theories suggest that one will regain lost weight unless intakes of total calories and fat are reduced. It was anticipated that exercise training would result in elevations in resting metabolic rate and increases in fat oxidation rates during rest and following meals. However, this did not happen, since resting metabolism remained stable and rates of fat oxidation following a meal either remained stable or, as in the case of the aerobic exercise group, decreased even further.

Thus, the physiological impetus (ie, decreased resting metabolism, and reduced rates of fatty acid oxidation during rest and following a meal) for weight regain remained despite the exercise training. This suggests that exercise-induced increases in resting metabolism and fatty acid oxidation during rest and following meals are not the mechanism(s) by which exercise training facilitates weight maintenance at reduced levels.

The reduction in body weight (−2.5 kg) with aerobic training and the increase in fat-free mass (1.5 kg) following weight training should not be unexpected, since these adaptations commonly occur following these endeavors. For example, in a meta-analysis, Ballor and Keesey[11] reported that, on average, aerobic (run/walk) exercise training resulted in reductions in body weight of 1.3 and 0.6 kg, respectively, for males and females. They further noted that the magnitude of weight loss was directly related to the level of obesity at the initiation of the training regimen. Wood et al[12] reported that walking 3 days per week resulted in overweight men reducing their body mass by 3.0 kg over a 7-month period. Thus, the additional weight loss in the aerobic training group may reflect a normal adaptation that occurs following initiation of an exercise training regimen.

Table 3. Postprandial Metabolism During the 5-Hour Period Following a Meal (mean ± SE)

Variable	WT Postdiet	WT Follow-up	WT Change	AT Postdiet	AT Follow-up	AT Change
Mean size (kcal)	810 ± 71	810 ± 71		774 ± 50	774 ± 50	
Thermic effect (kcal/5 h)	49.6 ± 6.7	65.9 ± 6.5	16.3 ± 8.9	58.0 ± 9.1	56.5 ± 9.1	−1.5 ± 8.1
Nonprotein respiratory exchange ratio	0.91 ± 0.02	0.94 ± 0.02	0.03 ± 0.02	0.93 ± 0.02	0.95 ± 0.01	0.02 ± 0.02
Percent kcal as fat (%)	24.1 ± 6.2	24.2 ± 5.8	0.01 ± 8.7	24.5 ± 5.5	12.8 ± 3.7	−11.6 ± 5.3
Energy expenditure (kcal/min)						
Total	1.26 ± 0.08	1.36 ± 0.09*	0.10 ± 0.03*	1.20 ± 0.07	1.19 ± 0.07	−0.01 ± 0.02*
Fat	0.29 ± 0.08	0.36 ± 0.10	0.07 ± 0.13	0.31 ± 0.07	0.15 ± 0.04	−0.16 ± 0.07
Carbohydrate	0.82 ± 0.11	0.84 ± 0.04	0.02 ± 0.11	0.75 ± 0.05	0.85 ± 0.08	0.10 ± 0.07
Protein	0.15 ± 0.02	0.16 ± 0.01	0.01 ± 0.02	0.14 ± 0.02	0.19 ± 0.01*	0.05 ± 0.02

NOTE. See Table 1 for abbreviations and definitions.

Likewise, the weight training adaptations are not dissimilar to those reported by Ballor and Keesey,[11] in which body mass and fat-free mass of males increased by 1.2 and 2.2 kg, respectively, in the exercise training studies surveyed, while fat mass decreased (1.0 kg). Similarly, Ballor et al[13] and Nichols et al[14] reported that weight training exercise in obese women resulted in a slight increase in body mass (0.4 to 0.8 kg), while fat-free mass increased significantly (1.1 to 1.5 kg), with percent body fat also being significantly reduced (0.9% to 1.2%).

The additional weight loss by the aerobic training group as compared with the weight training group may be a function of the energy expenditure of the exercise training itself. Based on the speed and grade at which subjects were walking,[15] aerobic training subjects expended approximately 430 kcal per exercise session. This is substantially more than the 150 kcal reported by Ballor et al[13] for weight training exercise similar to that performed here. In addition, fat utilization during the exercise period itself likely varied between aerobic and weight training as well. Ballor et al[13,16] reported that the respiratory exchange ratio during exercise for obese subjects was 1.03 and 0.80, respectively, for weight training and moderate-intensity aerobic exercise, suggesting that fat oxidation is much higher during aerobic exercise training as compared with weight training. Furthermore, aerobic exercise has been shown to result in increased (compared with rest) rates of fatty acid oxidation during the 3-hour period following cessation of an exercise bout.[17]

In conclusion, the physical changes (Table 1) that occurred consequent to either aerobic or weight training exercise did not seem to have been affected by the weight loss that immediately preceded the exercise training. In addition, for these subjects, exercise training did not attenuate the reductions in either resting energy expenditure or postprandial fat metabolism that occurred following weight loss. Thus, one may have to look elsewhere to explain the mechanism(s) by which exercise training facilitates the maintenance of weight at reduced levels.

REFERENCES

1. NIH Technology Assessment Conference Statement: Methods for voluntary weight loss and control. Ann Intern Med 116:942-949, 1992
2. King AC, Tribble DL: The role of exercise in weight regulation in nonathletes. Sports Med 11:331-349, 1991
3. Flatt JP: The difference in the storage capacities for carbohydrate and for fat, and its implications in the regulation body weight. Ann NY Acad Sci 499:104-123, 1987
4. Kayman S, Bruvold W, Stern JS: Maintenance and relapse after weight loss in women: Behavioral aspects. Am J Clin Nutr 52:800-807, 1990
5. Weir JB: New methods for calculating metabolic rate with special reference to protein. J Physiol (Lond) 109:1-49, 1949
6. Poehlman ET, McAuliffe T, Van Houten DR, et al: Influence of age and endurance training on metabolic rate and hormones in healthy men. Am J Physiol 259:E66-E72, 1990
7. Siri WE: Body composition from fluid spaces and density: Analysis of methods, in Brozek J, Henshel A (eds): Techniques for Measuring Body Composition. Washington, DC, National Academy of Sciences, 1961, pp. 223-244
8. Kirk RE: Experimental Design: Procedures for the Behavioral Sciences (ed 2). Monterey, CA, Brooks/Cole, 1982
9. Schutz Y, Flatt JP, Jequier E: Failure of dietary fat to promote fat oxidation: A factor favoring the development of obesity. Am J Clin Nutr 50:301-314, 1989
10. Schutz Y, Tremblay A, Weinsier RL, et al: Role of fat oxidation in the long-term stabilization of body weight in obese women. Am J Clin Nutr 55:670-674, 1992
11. Ballor DL, Keesey RE: A meta-analysis of the factors affecting exercise-induced changes in body mass, fat mass and fat-free mass in males and females. Int J Obes 15:717-726, 1991
12. Wood PD, Stefanick ML, Dreon DM, et al: Changes in plasma lipids and lipoproteins in overweight men during weight loss through dieting as compared with exercise. N Engl J Med 319:1173-1179, 1988
13. Ballor DL, Katch VL, Becque MD, et al: Resistance weight training during caloric restriction enhances lean body weight. Am J Clin Nutr 47:19-25, 1988
14. Nichols JF, Omizo DK, Peterson KK, et al: Efficacy of heavy-resistance training for active women over sixty: Muscular strength, body composition, and program adherence. J Am Geriatr Soc 41:205-210, 1993
15. American College of Sports Medicine: Guidelines for Exercise Testing and Prescription (ed 3). Philadelphia, PA, Lea & Febiger, 1986
16. Ballor DL, McCarthy JP, Wilterdink EJ: Exercise intensity does not affect the composition of diet- and exercise-induced body mass loss. Am J Clin Nutr 51:142-146, 1990
17. Bahr R, Hansson P, Sejersted OM: Triglyceride/fatty acid cycling is increased after exercise. Metabolism 39:993-999, 1990