Original Article

Effects of dumb-bell exercise with and without energy restriction on resting metabolic rate, diet-induced thermogenesis and body composition in mildly obese women

Tatsuhiro Matsuo[1]* PhD and Masashige Suzuki[2] PhD

[1]*Division of Nutrition and Biochemistry, Sanyo Women's College, Hiroshima, Japan*
[2]*Institute of Health and Sport Sciences, University of Tsukuba, Tsukuba, Japan*

The effects of dumb-bell exercise (aerobic-resistance exercise) with and without low calorie diet (LCD) therapy on resting metabolic rate (RMR), diet-induced thermogenesis (DIT) and body composition were studied in 12 mildly obese women aged 19–20 years. The subjects were randomly assigned to one of the following two groups: dumb-bell exercise with LCD (DEx + LCD group), and dumb-bell exercise only (DEx group). The subjects performed dumb-bell exercises with pairs of 2 kg dumb-bells every day after dinner for approximately 20 min. In the DEx + LCD group, subjects also received a liquid-formula diet based on a commercially available diet supplement, Micro Diet, for two of their three daily meals. Thus, they were restricted to approximately 4.18 MJ of energy intake per day for 12 weeks. Subjects underwent several measurements (body composition, RMR and DIT tests) before commencing the experiment and again after 12 weeks while still dieting. During the 12 week experimental period, body weight and body fat decreased significantly in both the DEx + LCD and the DEx groups without reducing fat free mass (FFM). The decreases in body weight and body fat were significantly larger in the LCD + DEx group than in the DEx group. These results suggest that dumb-bell exercise decreases body weight and body fat without reducing FFM in relation to increasing RMR and DIT. Micro Diet LCD may strengthen the effect of dumb-bell exercise on body weight and body fat, but weaken the effects on RMR and DIT.

Key words: dumb-bell exercise, low calorie diet, resting metabolic rate, diet-induced thermogenesis, body composition.

Introduction

Obesity is a major health problem in advanced nations.[1] It is associated with a significant increase in the incidence of hypertension, diabetes, coronary artery disease and mortality from certain types of cancer.[2,3] It is important when developing successful obesity treatment programs to define parameters that affect long-term treatment success. For example, there is no agreement about the optimum diet therapy for maximizing loss of body weight and body fat and for long-term maintenance of weight reduction. Exercise training and food restriction are the most popular therapies for obese individuals.[4] Many researchers recognize that food restriction has the most immediate weight reduction effect. Low calorie diets (LCD) and very low calorie diets (VLCD) are well-established weight loss strategies.[5–7] They have been proposed as a means of accelerating the active weight loss process. However, VLCD- or LCD-programs have been criticized for their failure to incorporate basic nutritional principles.[8] Concerns still exist regarding loss of fat free mass (FFM), which in turn may precipitate declines in resting metabolic rate (RMR).[9,10] Declines in RMR may ultimately inhibit subsequent weight loss and maintenance of weight loss.[9,10]

Exercise has been used with VLCD and LCD by many investigators in an effort to maintain FFM and prevent or reduce the loss of RMR. Aerobic exercises such as jogging, cycling or swimming are generally recommended because in a typical training session they result in a greater utilization of fat stores and greater energy expenditure than does anaerobic training.[11,12] However, aerobic exercise has shown equivocal results. Some investigators report reductions in losses of FFM,[13,14] while others report no loss of FFM above that caused by dieting without aerobic exercise.[15–18] Furthermore, it is difficult for many obese people to develop the habit of aerobic exercise training because of mental stress or orthopedic lesions.

Dumb-bell exercise (aerobic-resistance exercise with light-weight dumb-bells, which is popular in Japan and China) is much easier to instill as a habit compared with aerobic exercise. Dumb-bell exercise is safe and anyone can do it at any time and in any place. Suzuki *et al*. reported that dumb-bell exercise for 12 weeks reduced 2 kg of body fat without food restriction.[19] However, no studies have demonstrated immediate or drastic reduction of body weight and body fat with dumb-bell exercise only. It is not clear whether

Correspondence address: Dr Tatsuhiro Matsuo, Faculty of Agriculture, Kagawa University, Ikenobe, Mikicho, Kitagun, Kagawa 761–0795, Japan.
Tel: 81 87 891 3082; Fax: 81 87 891 3021.
*Present address: as above.
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or not dumb-bell exercise with LCD maintains FFM and prevents or reduces the loss of energy metabolism. The purpose of this study was to examine the effect of dumb-bell exercise with and without moderate energy restriction on RMR, DIT and body composition in mildly obese young women.

Methods

Subjects

Twelve young Japanese women, aged 19–20 years, who did not have a habit of daily exercise were recruited from Sanyo Women's College (Hiroshima, Japan) to participate in this study. All procedures were approved in advance by the Institutional Ethics Committee of Sanyo Women's College and were in accordance with the Helsinki Declaration of 1975, as revised in 1983. After a detailed explanation of this study, each subject gave her informed written consent. Except for obesity, the subjects were determined to be free of disease by a medical examination before the study. No subjects were using illegal drugs or taking medications that affect body weight. The day of the menstrual cycle when they began and ended the study was noted because fluctuations in metabolic parameters can occur during the cycle.[20] Subjects started the exercise program immediately after premetabolic tests. Because the study period was 12 weeks, most of the women were at about the same point of their cycle (mid-follicular phase) when RMR, DIT and body composition were remeasured as they were at the beginning.

The subjects were randomly assigned to one of the following two groups: (i) dumb-bell exercise combined with LCD (DEx + LCD group) or (ii) dumb-bell exercise only (DEx group). The base line characteristics of subjects belonging to the DEx + LCD group and DEx group are shown in Table 1.

Dumb-bell exercise

The subjects in both groups performed dumb-bell exercises with pairs of 2 kg dumb-bells every day after dinner. A warm-up of 5 min of stretching preceded the dumb-bell exercises. The dumb-bell exercises consisted of 12 movements used to exercise the upper and lower body large muscle groups. The exercises were standing shoulder press, bent dumb-bell row, squat, upper body twist, butterfly, bent lateral raise, simultaneous curl, concentration curl, one hand draw up, kickback, front dumb-bell raise, and arm extension.[21] The dumb-bell exercises trained the chest, shoulders, biceps, triceps, back, thighs and abdominals, mainly. Subjects performed 15 repetitions of each exercise, with 30 s of rest between the different exercises. Subjects grasped the dumb-bell bars firmly, and raised and lowered the weights slowly in a continuous motion. If subjects grew fatigued during the exercise, they performed a stretching exercise until they recovered their strength. Total exercise time each day was approximately 20 min.

Restrictive diet

The subjects in the DEx + LCD group received a liquid-formula diet based on a commercially available diet supplement (i.e., Micro Diet, Sunny Health Co. Ltd, Nagano, Japan) for 2 of their 3 meals per day, which provided 40% of daily energy intake. The subjects received normal Japanese food equivalent to approximately 2.10–2.51 MJ for one meal each day. Thus, they were restricted to approximately 4.18 MJ of energy intake per day. A formula diet was provided to improve control of energy intake. Two packages of powder (two meals) were taken daily. These contained the nutrients and composition of amino acids shown in Table 2 and Table 3. Subjects obtained >1.0 g protein/kg weight, an intake recommended to maximize increases in muscle growth.[12] Food consumption by the subjects is shown in Table 4.

Subjects were seen individually each week for nutritional counselling, with emphasis on behaviour modification that included recording daily food intake. Behaviour modification has been shown to improve long-term weight loss in association with a formula diet.[22,23] Subjects were asked to record and maintain their usual sedentary activity pattern during the study except for the exercise prescribed. Body compositions (body weight, percentage of body fat and circumference of waist and hip) were measured weekly in order to observe the development of the experiment.

Measurement procedures

Subjects underwent several measurements before starting the experiment and again after 12 weeks while still dieting. Mea-

Table 1. Pre- and post-experiment measurements

	Groups	
	DEx + LCD	DEx
Height (cm)	159.1 ± 2.9	161.1 ± 3.2
Weight (kg)		
Before	66.3 ± 5.4	61.1 ± 2.2
After	60.3 ± 4.6*	59.2 ± 2.2*
Change	–6.0 ± 1.4	–1.9 ± 0.5†
BMI (kg/m^2)		
Before	26.2 ± 2.1	23.6 ± 0.9
After	23.8 ± 1.7*	22.9 ± 0.8*
Change	–2.4 ± 0.3	–0.7 ± 0.1†
Body fat (%)		
Before	36.9 ± 3.3	31.6 ± 1.3
After	30.8 ± 2.1*	28.4 ± 1.6*
Change	–6.1 ± 0.6	–3.2 ± 0.2†
Body fat (kg)		
Before	24.5 ± 3.5	19.3 ± 1.1
After	18.6 ± 2.6*	16.9 ± 1.3*
Change	–5.8 ± 1.2	–2.4 ± 0.3†
FFM (kg)		
Before	41.8 ± 1.9	41.8 ± 1.6
After	41.6 ± 2.1	42.3 ± 1.4
Change	–0.2 ± 0.5	0.5 ± 0.5
Waist (cm)		
Before	77.9 ± 4.6	69.8 ± 1.9
After	70.6 ± 3.4*	67.4 ± 1.1
Change	–7.2 ± 2.7	–2.4 ± 1.2†
Hip (cm)		
Before	96.7 ± 4.1	95.3 ± 1.7
After	93.6 ± 2.9*	93.3 ± 1.4
Change	–3 .1 ± 1.4	–2.0 ± 1.2
Waist/hip ratio		
Before	0.81 ± 0.03	0.73 ± 0.01
After	0.75 ± 0.03*	0.72 ± 0.01
Change	–0.05 ± 0.02	–0.01 ± 0.01

Values are means ± SEM for six subjects. FFM, fat free mass.
*Significantly different from pre-experiment value (Student's paired *t*-test), $P < 0.05$. †Significantly different from DEx + LCD group (Student's unpaired *t*-test), $P < 0.05$.

surements at the end were conducted >24 h after the previous exercise session. Subjects were requested to fast for 12 h beforehand and void bowels and bladder in the morning. The technicians performing the procedures were blind to the subjects' group assignments. The procedures were performed in the following order: RMR, DIT, and body composition. All procedures were performed in an experiment laboratory room under the same conditions (temperature, 22 ± 1°C; humidity, 60%).

Resting metabolic rate and diet-induced thermogenesis tests

The DIT test meal consisted of bread and butter, a boiled egg, boneless ham, orange juice, an apple and yogurt. It provided energy as carbohydrate (58%), fat (24%) and protein (18%).

Table 2. Daily Micro Diet nutrients in two packages

Nutrients	Nutrients/80 g Micro Diet
Protein (g)	40.6
Carbohydrate (g)	24.7
Fat (g)	5.4
Vitamin A (IU)	2000.0
Vitamin B1 (mg)	1.3
Vitamin B2 (mg)	1.3
Vitamin B6 (mg)	2.0
Vitamin B12 (μg)	3.3
Niacin (mg)	10.0
Pantothenic acid (mg)	4.7
Vitamin C (mg)	46.7
Vitamin D (IU)	266.7
Vitamin E (mg)	6.7
Calcium (mg)	600.0
Iron (mg)	13.3
Zinc (mg)	13.3
Magnesium (mg)	233.3
Manganese (mg)	1.9
Copper (mg)	1.3
Sodium (mg)	1000.0
Potassium (mg)	1340.0
Energy (kJ)	1340.0

Table 3. The composition of amino acids in Micro Diet

	Amino acids (g/100 g)
Isoleucine	2.55
Leucine	4.49
Lysine	3.76
Methionine	1.28
Tyrosine	2 37
Phenylalanine	2.63
Threonine	2.11
Tryptophan	0.68
Cysteine	0.39
Valine	3.08
Histidine	1.45
Arginine	2.36
Alanine	1.80
Aspartic acid	4.35
Glutamic acid	10.70
Glycine	1.33
Proline	4.69
Serine	2.65

The energy of the test meal was 2.53 MJ. Resting metabolic rate and DIT tests were determined at 10:00–13:45 h after the subject rested comfortably for 45 min, in a supine position, while trying not to move or fall asleep. The subjects were fed a test meal at 10:30–10:45 h. The subjects then rested for 3 h (10:45–13:45 h). During rest, oxygen uptake and respiratory exchange ratio (R) were measured. Blood samples were collected from the cephalic vein at the level of the forearm to obtain serum and plasma at 10:30, 11:00, 11:30, 12:00, 12:30, and 13:30 h.

Measurements

Indirect calorimetry was performed by the ventilated hood technique. For measurement of oxygen uptake and R, the subjects wore face masks (Takei Co. Ltd, Tokyo, Japan) continuously for 225 min, except during meal times (15 min). All expired gas was collected into a Douglas bag (Takei Co. Ltd), and the bag was changed every 15 min during rest. The concentrations of oxygen and carbon dioxide in the expired collected gas were immediately analysed by a gas analyser (Model RAS-30, RAS-40, AIC Co. Ltd, Tokyo, Japan). Energy expenditure was calculated from oxygen consumption and carbon dioxide production, corrected for urinary nitrogen loss as described by Consolazio *et al*.[24] The R was also calculated and used as an index of carbohydrate and fat utilization. Energy expenditure of DIT was determined by the formula:

$$\text{post-meal total energy expenditure } (\text{PTEE}_{180\text{ min}}) - \text{RMR}_{180\text{ min}}$$

Plasma glucose was assayed using a glucose analyser with electrochemical detection (Model GA-1140; Kyoto Daiichi Co. Ltd, Kyoto, Japan) and a kit (GLC-C) purchased from Kokusai Shiyoku Co. Ltd (Kobe, Japan). Serum triacylglycerol (TG) and free fatty acids (FFA) were determined enzymatically with kits (TG-A, NEFA-V5) purchased from Kokusai Shiyoku Co. Ltd and Nippon Shoji Co. Ltd (Osaka), respectively. Serum immunoreactive insulin was determined by radioimmunoassay (two-antibody system) with kits (Insulin 'Eiken') purchased from Eiken Chemical Co. Ltd (Tokyo, Japan). Rhw 3 h area under the curve for glucose, insulin, TG and FFA was calculated by time integration using

Table 4. Mean energy consumption of subjects per week

Week	Groups (MJ/day)	
	DEx ± LCD	DEx
1	3.82 ± 0.16	7.27 ± 0.16
2	4.15 ± 0.15	7.51 ± 0.17
3	3.88 ± 0.19	7.40 ± 0.30
4	3.75 ± 0.22	7.24 ± 0.29
5	3.96 ± 0.13	6.90 ± 0.15
6	3.82 ± 0.18	7.36 ± 0.37
7	4.10 ± 0.30	7.13 ± 0.43
8	3.86 ± 0.26	6.83 ± 0.58
9	4.13 ± 0.24	6.89 ± 0.41
10	4.14 ± 0.35	7.39 ± 0.36
11	3.91 ± 0.30	7.29 ± 0.35
12	3.82 ± 0.21	7.30 ± 0.37

Values are means ± SEM for six subjects. DEx, dumbbell exercise; LCD, low calorie diet.

a personal computer (Macintosh LC 575; Apple Japan Inc., Tokyo, Japan).

Body composition

The subjects' height and weight were measured by conventional methods. Percentage of body fat, fat mass and FFM were determined by bioelectrical impedance analyser (Model TBF-102; Tanita Co. Ltd, Tokyo, Japan). Waist and hip measurements were taken conventionally using a tape measure, before the waist to hip (W/H) ratio was found.

Statistical analysis

Statistical analysis was conducted using a personal computer (Macintosh LC 575; Apple Japan Inc.) with a statistical package program (Stat View 4.02; Abacus Concepts Inc., Berkeley, CA, USA). Data were analysed using Student's unpaired *t*-tests to show differences in variables between groups. Changes in variables within groups from baseline to 12 weeks were compared using Student's paired *t*-tests.

Results

Body weight and body composition

Mean body weight, body mass index (BMI), percentage of body fat and body fat weight were significantly reduced in the two groups ($P < 0.05$), and the differences were greater in the DEx + LCD group than in the DEx group ($P < 0.05$) (Table 1). Decreases in percentage body fat were 6.2% and 3.1% for the DEx + LCD group and DEx group, respectively. However, the change in FFM was negligible in both groups for the 12 week experimental period (Table 1).

Mean waist and hip size significantly decreased ($P < 0.05$) in the DEx + LCD group (Table 1). The decrease in waist size was greater in the DEx + LCD group than in the DEx group ($P < 0.05$) (Table 1). The DEx + LCD group significantly reduced their W/H ratio ($P < 0.05$) (Table 1).

Resting metabolic rate and diet-induced thermogenesis

Resting metabolic rate, DIT and PTEE adjusted for body weight increased significantly in the DEx group ($P < 0.05$) (Table 5). The changes in RMR, DIT and PTEE were greater in the DEx group than in the DEx + LCD group ($P < 0.05$) (Table 5). However, the change in basal and postprandial *R* were negligible in both groups for the 12 week experimental period (Table 5).

Plasma glucose, serum insulin, triacylglycerol and free fatty acids

Fasting plasma glucose concentration and 3 h glucose area (calculated from glucose concentration approximate time curve) significantly decreased in the two groups ($P < 0.05$), without differing between them (Table 6). Fasting and 3 h area of serum insulin did not change in either group for the 12 week experimental period (Table 6). Fasting serum TG concentration and 3 h TG area significantly decreased in both groups ($P < 0.01$) without differing between them (Table 6).

Discussion

The results show that dumb-bell exercise for 12 weeks with and without energy restriction significantly decreased body weight and body fat without reducing FFM. The decreases in body weight, percentage body fat, body fat weight and BMI were significantly larger when dumb-bell exercise was combined with LCD. These results support our previous findings.[19,25]

Exercise, either aerobic or anaerobic, has been used with restricted diet programs in an effort to maintain FFM. Aerobic exercise is generally recommended for combination with restrictive diets, but aerobic exercise has shown equivocal results. Some researchers have suggested that FFM can be maintained[13,14] while others have reported contrary results.[15–18] Recently, many reports have described the effects of resistance exercise on reducing body weight and body fat mass. Ballor *et al*. suggested that FFM increases in response to resistance training in obese women with an energy deficit of 4.18 MJ below baseline caloric requirements.[26] Diet plus resistance training in their study produced an increase of 0.43 kg FFM. However, Donnelly *et al*.[27] reported a considerable loss of FFM (4.7 kg) through resistance exercise training combined with VLCD. Giliebter *et al*. also suggested that restricted diets (5.02 MJ) plus resistance exercise decreased FFM by 1.1 kg.[28] The present study showed a decrease of 0.2 kg FFM for the DEx + LCD group. The disagreement concerning the effects of resistance exercise combined with restrictive diet on FFM may be due to the quality or quantity of training or diet during the experimental period.

No clear method for resistance training while dieting has been established. In fact, the dumb-bell exercise is not resistance weight training but aerobic-resistance exercise. Because a fixed light weight (2–5 kg) is used for the dumbbell exercise, little or no weight gain by muscle hypertrophy is produced. However, dumb-bell exercise does stimulate protein turnover and energy metabolism.[19,25,29] We recently reported that iron binding proteins in serum were increased

Table 5. Pre- and post-experiment metabolic test results

	Groups	
	DEx + LCD	DEx
RMR (J/kg per min)		
Before	66.8 ± 2.3	66.2 ± 1.8
After	67.1 ± 2.1	68.3 ± 1.2*
Change	0.3 ± 0.2	2.1 ± 0.5†
DIT (kJ/kg per 3 h)		
Before	3.31 ± 0.52	3.02 ± 0.43
After	3.39 ± 0.61	3.84 ± 0.41*
Change	0.08 ± 0.03	0.82 ± 0.16†
PTEE (J/kg per min)		
Before	83.7 ± 3.5	82.8 ± 2.7
After	86.3 ± 2.6	88.8 ± 2.6*
Change	2.6 ± 0.5	6.0 ± 0.3†
R (basal)		
Before	0.81 ± 0.02	0.80 ± 0.02
After	0.79 ± 0.02	0.79 ± 0.01
Change	0.02 ± 0.01	0.01 ± 0.01
R (postprandial)		
Before	0.84 ± 0.02	0.83 ± 0.02
After	0.83 ± 0.02	0.83 ± 0.02
Change	0.01 ± 0.01	0.00 ± 0.01

Values are means ± SEM for six subjects. RMR, resting metabolic rate; DIT, diet-induced thermogenesis; PTEE, post-meal total energy expenditure. *Significantly different from pre-experiment value (Student's paired *t*-test), $P < 0.05$. †Significantly different from DEx ± LCD group (Student's unpaired *t*-test), $P < 0.05$.

with 12 weeks of dumb-bell exercise.[30] Our present findings demonstrate that dumb-bell exercise significantly increased RMR and DIT, particularly without energy restriction. Given that it has been reported that RMR and DIT are mediated by the sympathetic nervous system (SNS),[31–33] the effects of dumb-bell exercise on energy metabolism may be related to SNS activity. It has been suggested that moderate exercise increases SNS activity in both rats[34] and humans.[35]

Glucose and TG disposition from blood after test meal ingestion were significantly increased with dumb-bell exercise without altering serum insulin (fasting and 3 h area). These findings suggest that insulin sensitivity to glucose and lipoprotein lipase (LPL) activities in peripheral tissues, especially heart or skeletal muscle, are increased by dumb-bell exercise. The site of physiological action by LPL is the luminal surface of capillary endothelial cells where the enzyme hydrolyses the triacylglycerol component of circulating lipoprotein particles, chylomicrons and very low density lipoproteins.[36] However, dumb-bell exercise with or without energy restriction did not alter basal and postprandial *R* levels, indicating that the fat oxidation rate did not change.

Table 6. Pre- and post-experiment blood analysis results

	Groups	
	DEx + LCD	DEx
Fasting glucose (mg/100 mL)		
Before	88.3 ± 0.6	88.5 ± 0.7
After	82.5 ± 2.3*	81.0 ± 2.7*
Change	–5.8 ± 1.8	–7.5 ± 2.4
3 h glucose area (mg/100 mL) × min × 10^3		
Before	17.7 ± 0.9	18.1 ± 0.8
After	16.3 ± 0.9*	15.8 ± 0.8*
Change	–1.4 ± 0.6	–2.3 ± 0.2
Fasting insulin (μU/mL)		
Before	9.0 ± 0.9	8.7 ± 0.6
After	11.1 ± 2.0	8.8 ± 1.1
Change	–2.1 ± 0.2	0.1 ± 1.2
3 h insulin area (μU/mL) × min × 10^3		
Before	8.0 ± 0.9	7.9 ± 0.6
After	7.2 ± 1.0	7.5 ± 0.8
Change	–0.8 ± 0.5	–0.4 ± 0.5
Fasting triacylglycerol (mg/100 mL)		
Before	94.0 ± 15.1	89.2 ± 13.7
After	68.2 ± 3.7*	65.8 ± 4.4*
Change	–25.8 ± 2.7	–23.4 ± 3.2
3 h triacylglycerol area (mg/100 mL) × min × 10^3		
Before	19.8 ± 2.7	19.7 ± 1.4
After	15.4 ± 1.2*	15.5 ± 0.8*
Change	-4.4 ± 1.4	-4.2 ± 1.2
Fasting free fatty acids (mmol/L)		
Before	449 ± 78	412 ± 49
After	400 ± 60	421 ± 50
Change	–49 ± 27	9 ± 12
3 h free fatty acids area (mmol/L) × min × 10^3		
Before	36.2 ± 4.8	35.5 ± 4.1
After	36.3 ± 4.4	38.0 ± 3.2
Change	0.1 ± 1.4	2.5 ± 1.2

Values are means ± SEM for six subjects. *Significant different from pre-experiment value (Student's *t*-test), $P < 0.05$.

In this context, it should be noted that the fasting and 3 h area of serum FFA were not altered by 12 weeks of dumb-bell exercise.

In the present study, subjects performed dumb-bell exercises every day after dinner. It is recognized that exercise timing is important to fat utilization, glycogen synthesis, and muscle reproduction.[37,38] Exercise after meals burns chylomicron–triacylglycerol from dietary fat more than exercise before meals.[38] Moreover, exercise after dinner is best for maintaining muscle protein because muscle protein synthesis is higher during sleep.[39]

In conclusion, our study suggests that dumb-bell exercise decreases body weight and body fat without reducing FFM in relation to increasing RMR and DIT. Low calorie diets may strengthen the effect of dumb-bell exercises on body weight and body fat but weaken the effects on RMR and DIT.

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