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Effects of a High Protein Diet and Aerobic Exercise on Body Weight Changes and Blood Lipids in Slightly Overweight Women

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To examine the combined effects of a high-protein diet and aerobic exercise on body weight and composition and blood lipid profiles in overweight women, 30 young women were recruited and placed into three groups: The high-protein diet and exercise group (HPE), the exercise-only group (EXO) and the control group (CON) (30±3%, 27±2%, and 29±3% body fat, respectively) for an 8-week experimental period. Daily diet included 25% isolated soybean protein (>90% protein, approximately 400 kcal) combined with each subject's usual diet for the HPE group. The exercise program consisted of aerobic-type exercises undertaken >3 times/wk and for >30 min/session at 50-60% of maximal capacity. Physical fitness, body composition, serum total cholesterol (TC), high-density lipoprotein-cholesterol (HDL-C), triglycerides (TG) and glucose were measured before and after the experiment. Maximal aerobic capacity increased by the end of experiment in both the HPE (from 27.2±3.5 to 35.1±5.9 ml/kg/min, $p<0.01$) and EXO (from 30.3±5.4 to 33.8±3.8 ml/kg/min, $p<0.05$) groups. Percent body fat decreased by 3.3% ($p<0.01$) in the HPE group and by 1.5% ($p<0.05$) in the EXO group by the end of the experiment, but not in the CON group. Lower back strength and agility increased only in the HPE group. In the HPE group, TC decreased from 168±20 to 155±18 mg/dL and HDL-C increased from 57±10 to 61±9 mg/dL in HPE ($p<0.01$). But TC and HDL-C did not change in the EXO and CON groups. TG and glucose did not vary among the groups. Although the EXO group showed a similar outcome to that of the HPE group, a favorable change in body composition and blood lipids as well as an improvement in aerobic capacity was more marginal in the latter group.

Key words: Weight reduction, Isolated soybean protein, Dietary protein, Body fat

INTRODUCTION

Being overweight or obese is recognized as a risk factor for various health and medical problems in industrialized countries.[1)] Overweight-related health problems include hypertension, diabetes, certain types of cancer, cardiovascular diseases, osteoarthritis and hyperinsulinemia.[2-8)] Since being overweight is thought to be related to decreased physical activity and positive caloric balance, the implementation of exercise and dietary interventions is recommended to control the risks associated with being overweight. Many research findings support the favorable effects of both exercise and diet interventions for weight and body fat reduction.[9,10)] When those who exercise succeed with even modest weight loss, this helps reduce mortality and morbidity.[9)]

Several dietary recommendations affecting body weight reduction have been suggested, including reduced energy intake, very-low-calorie diets and changes in macronutrient composition.[8)] When energy intake falls below what the body needs, weight loss occurs.[11)] Compared to conservative methods of reducing energy intake, very-low-calorie diets (defined as energy intake <800 kcal/d) elicited a greater magnitude and rate of weight loss.[12)] But the use of very-low-calorie diets should be limited to relatively short periods of time and used in conjunction with dietary supplements and medical supervision.[8)] Changes in diet composition have also been recommended as weight loss strategies. Reductions in both dietary fat and energy intake produce greater weight loss.[13)] Also, it has been suggested that increasing the protein portion of the diet could be beneficial in achieving weight loss. The rationale for this is based on increased thermogenesis and satiety[14,15)] concomitantly reducing overall energy intake.

High-protein diets have been found to reduce body fat significantly.[16,17)] It has been demonstrated that the use of a high-protein diet with reduced caloric intake for 6 months results in a significant reduction of body weight, body fat and body mass index.[17)] But uncontrolled high-protein diets generally induce energy deficit.[8)] And

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high-protein diets of up to 40% of dietary composition may have adverse effects such as glycogen reduction due to a reduced supply of carbohydrates and ketosis.[16] But below this level of protein, it may not have harmful effects.[18]

Exercise also accentuates weight changes by increasing energy expenditure and reduced body weight can improve health status. Although exercise can induce weight loss,[19] exercise alone may not produce a similar magnitude of weight reduction when compared to a combined intervention of diet and exercise.[8,20] Research findings suggest the combination of dietary modification and exercise is the most effective approach to weight reduction and maintenance.[20,22] However, combined interventions involving exercise and a high-protein diet have not been extensively investigated.

Thus, it is of interest to investigate the combined effects of a high-protein diet and aerobic exercise on weight management in people who are overweight. In the present study, the effect of a 25% high-protein diet with isocaloric energy intake and aerobic exercise on body weight changes and blood lipid levels was examined in slightly overweight women who had no experience of systemic diet and exercise modification.

SUBJECTS AND METHODS

1. Subjects

A total of 30 women who met the criteria for this study were recruited. The selection criteria were 20-30 yrs, >25% body fat content, no involvement in regular exercise and diet programs in the 6 months prior to this study, no abrupt weight reductions in the past three months, no reported medical and health problems, and no known metabolic and cardiovascular diseases. A detailed experimental procedure was outlined to each subject and a written informed consent was obtained. The study was approved by the institutional review board.

2. Study Design

Subjects were equally and randomly divided into three groups: A high-protein diet and exercise participation group (HPE: n=10, 23.8±1.8 yrs, 160.8±5.5 cm, 59.1±3.6 kg) an exercise-only group (EXO: n=10, 24.6±3.2 yrs, 160.4±7.1 cm, 57.1±10.2 kg) and a control group (CON: n=10, 25.0±1.9 yrs, 159.7±3.3 cm, 56.8±5.0 kg). The exercise and high protein consumption programs lasted for 8 weeks for the HPE and EXO subjects. Before beginning the program, baseline tests including body composition, physical fitness tests and blood lipid parameters were conducted. The same tests were conducted at the end of the program. During the 4th week of the program, each subject's body composition was measured again (Fig. 1). Subjects in the CON group maintained their normal diet and physical activity during the experimental period.

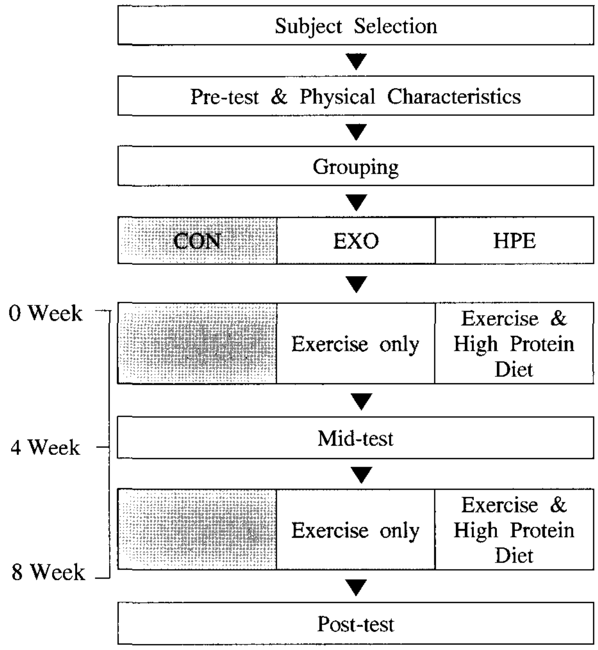

Fig. 1 Schematic Expression of Experimental Design

3. High Protein Diet Regimens

Daily meals for the HPE group were manipulated and included 25% of daily caloric value by isolated soybean protein. The soybean product was composed of more than 93% protein, 0.2% fat and 6% moisture (distributor, Kwang Il Co., Korea). The soybean protein provided >90% of daily total protein intake with an approximate value of less than 400 kcal. Each HPE subject was provided with packages of powder-type soybean protein meals (100 g/day) and was instructed to consume it as a substitute for breakfast. For the preparation of the meal, they mixed the soybean powder with 500 mL of water. To cope with taste problems, they were allowed to add vanilla flavoring to the mixture. To match the pre-experimental daily caloric intake, carbohydrate intake was reduced. Everyday diet was targeted to maintain the daily isocaloric value. All of the other subjects were requested to maintain their standard daily diet throughout the experimental period. They were asked to keep a three-day dietary record including two weekdays and one weekend day.

4. Exercise Program

The exercise program was undertaken >3 times/wk and for >30 min/session at an intensity of 50-60% of individual maximal heart rate (HR). During each exercise session, each subject's HR was monitored by Polar HR monitor (CE0537, Polar, Finland) and the exercise intensity was readjusted in the 4th week of the program according to the subject's HR responses. Subjects participated in aerobic types of exercise including fast walking, jogging, running and stationary biking. Exercise sessions were supervised by the investigators.

5. Measurements and Calculations

Body weight and height were measured on a digital balance with the subjects in minimal clothing (150A CAS, Korea) using a digital scale (DT-102, Jenix, Korea). Body mass index was calculated as weight/height^2. Percent body fat was estimated by bio-impedance (GIF-891DX, Gilwoo, Korea). Skinfold thickness in mm was taken using a skinfold caliper (Jamar, Japan) at nine sites: Chest, subscapular, side, suprailium, abdomen, triceps, biceps, thigh and calf and mean skinfold thickness was calculated as summation of the nine values divided by nine.

Cardiorespiratory endurance was measured using maximal aerobic exercise testing on a cycle ergometer (Aerobike, Combi 75 XL, Japan). Subjects pedalled at 50 load was increased by 15 Watt every min. During the test, maximal HR was recorded and the value was used to calculate individual workload range using the equation [(maximal HR-resting HR)×0.5 (or 0.6)]. Muscular strength was evaluated by lower back strength (SH-9600E, Sewoo, Korea) and grip strength in kg.[23] Muscular endurance was examined using a sit-up test while 90 ℃ bent knee for 30 sec.[24] Agility and flexibility was measured by side-step for 20 sec and sit-and-reach for cm, respectively. For the side-step, subjects moved both feet as fast as they could over three parallel lines, which were 1 m apart.[24]

During the baseline test, about 20 cc of blood was drawn from the antecubital veins in the morning after a 10-hour overnight fast. Blood samples were analyzed for serum total cholesterol (TC), high-density lipoprotein-cholesterol (HDL-C), triglycerides (TG) and glucose (Ektachem, DT60II system, Johnson & Johnson, U.S.A.) according to the manufacturer's instructions. Low-density lipoprotein cholesterol (LDL-C) was calculated using Friedewald's formula. Dietary composition and caloric intake were evaluated using computerized nutritional analysis software (CAN-pro 2.0, Korean Nutrition Society).

6. Statistical Analyses

A computerized statistical package (Windows SPSS version 10.0) was used for the analyses. Each variable was expressed as mean and standard deviation. To compare groups and testing periods, two-way ANOVA with repeated measures was employed. Two-way ANOVA was also employed to analyze blood variables. When a significant F ratio was found, Student- Newman-Kuels Multiple Range Test was employed for further analyses. One-way ANOVA was utilized when appropriate. Statistical significance was considered when $p<0.05$.

RESULTS

1. Changes in Physical Characteristics

Changes in morphological and cardiovascular characteristics during the experimental period are shown in Table 1. Body weight had decreased by 2 kg by the end of the experiment in the HPE and EXO groups ($p<0.05$). Body mass index also decreased in relation to the baseline ($p<0.05$) in the HPE and EXO groups by the end of the experiment. Body mass index was lower in the EXO group than in the CON group at the end of the study ($p<0.05$).

While no changes were noticed in % body fat in the CON group throughout the experiment, that in the HPE and EXO groups decreased by 3.3±2.1% and 1.5±1.6% by the end of the experiment ($p<0.05$). By that time, %

Table 1. Changes of Physical Characteristics during the Experiment

Group	Week	Weight (kg)	Body Mass Index (kg/m^2)	Percent Body Fat (%)	Waist-to-Hip Ratio	Mean Arterial Pressure (mmHg)	Resting Heart Rate (beat · min^{-1})	Maximal Oxygen Consumption (ml · kg^{-1} · min^{-1})
CON	0	56.8±5.0	21.3±1.8^{*a}	28.9±3.0	0.73±0.04	81.0±6.3	80.3±6.3	28.3±4.7
	4	56.9±5.4	21.6±1.8	29.1±2.9	0.73±0.04	79.8±6.5	79.8±6.5	29.2±3.7
	8	57.4±5.4	22.0±2.2	28.7±2.8	0.73±0.04	81.8±7.5	81.8±7.5	30.1±4.2
HPE	0	59.1±3.6	21.9±1.7*	29.7±3.4^{c}	0.72±0.04	82.4±12.5	76.1±6.4	27.2±3.5
	4	57.6±4.1	22.3±1.9^{c}	27.5±3.5*	0.71±0.04	81.3±10.2	75.3±8.1	32.3±5.0*
	8	56.7±3.5	22.9±1.7^{ac}	26.4±2.3*	0.72±0.05	82.1±7.6	71.9±6.1	35.1±5.9^{*a}
EXO	0	57.1±10.2	22.4±1.7	26.8±2.2^{a}	0.76±0.04	79.6±5.3	68.6±8.5	30.3±5.4
	4	56.1±9.6	22.2±1.6	26.8±2.5^{a}	0.76±0.03	78.4±10.4	71.9±10.4	33.3±4.8
	8	55.2±9.7^{*a}	22.2±1.3	25.3±2.5^{*a}	0.76±0.03	80.1±8.5	71.5±10.0	33.8±3.8^{*a}

HPE: high protein diet and exercise participation group; EXO: exercise participation only group; CON: control group;
* Significantly different compared to the 0 week at $p<0.05$
a, c Significantly different compared to the same testing period of group CON and EXO, respectively, at $p<0.05$

body fat was lower in the EXO group than in the CON group ($p<0.05$). The waist-to-hip ratio did not change among testing periods and groups.

There was no difference in mean arterial pressure and resting HR among the groups and testing periods. The maximal aerobic capacity estimated by oxygen consumption rose in both the 4th and 8th weeks in the HPE group, and in the 8th week in the EXO group compared to the respective baselines ($p<0.05$). However, no changes were noticed in the CON group. The maximal aerobic capacity in the 8th week was higher in the HPE and EXO groups than in the CON group ($p<0.05$).

Mean skinfold thickness decreased in the HPE and EXO groups in the 8th week of the experiment compared to the baseline (Table 2). And the values in the 8th week for the HPE and EXO groups were lower than that for the CON group. In general, individual skinfold thickness decreased mainly from the limbs and upper trunk in the HPE group, and from the trunk in the EXO group, while no changes in individual skinfold sites were observed in the CON group.

Table 2. Changes of Skinfolds during the Experiment

Sites (mm)	Week	Group		
		CON	HPE	EXO
Chest	0	17.9±4.5	18.4±5.2	16.7±5.6
	4	16.3±3.5	15.7±3.1	15.6±5.6
	8	17.6±2.9	13.0±2.6*[a]	14.2±4.2[a]
Subscapular	0	18.9±4.9	21.3±6.2	22.4±7.0
	4	17.2±5.3	17.8±4.0	21.6±7.5[a]
	8	19.2±7.1	16.9±3.7*	19.8±4.5
Side	0	16.5±4.8	17.0±3.6	21.0±8.9
	4	16.7±5.1	15.8±3.4	19.0±6.2
	8	17.6±4.5	15.2±3.3	16.9±5.4*
Suprailium	0	15.0±3.4	17.3±4.6	19.5±6.3
	4	16.8±5.7	15.1±3.9	15.5±8.0*
	8	16.8±3.7	15.3±4.0	13.7±4.7*
Abdomen	0	24.5±5.3	24.6±4.4	25.1±6.2
	4	25.4±5.0	23.4±4.3	23.3±6.4
	8	25.9±5.1	23.4±3.8	21.9±4.5*[a]
Triceps	0	25.0±5.0	26.3±6.0	24.8±7.8
	4	23.4±5.0	22.9±6.4*	21.4±4.8*
	8	23.8±5.1	22.2±5.3*	20.0±3.7*[a]
Biceps	0	16.8±6.9	16.5±8.0	16.1±5.3
	4	16.8±6.9	15.1±7.9	15.5±4.9
	8	16.5±7.4	12.8±4.8*[a]	15.3±4.4
Thigh	0	33.1±10.0	34.1±10.1[c]	27.0±3.7
	4	31.7±10.1	30.5±8.8	25.0±5.4[a]
	8	33.8±10.4	28.6±7.0*	22.8±4.1[a]
Calf	0	20.3±7.5	22.2±8.8	20.1±5.5
	4	17.7±6.9	19.1±7.7	16.7±4.4
	8	20.5±7.0	17.6±6.0*	13.7±4.0*[a]
Mean Skinfolds Thickness	0	20.9±4.6	21.9±5.5	21.4±5.2
	4	20.2±5.0	19.5±9.8	19.3±5.0
	8	21.3±5.4	18.3±3.6*[a]	17.6±3.2*[a]

HPE: high protein diet and exercise participation group;
EXO: exercise participation only group; CON: control group;
Mean Skinfolds Thickness = ($\sum$9 sites skinfold÷9)
* Significantly different compared to the 0 week at $p<0.05$
[a, c] Significantly different compared to the same testing period of group CON and EXO, respectively, at $p<0.05$

2. Dietary Composition and Caloric Intake

Dietary behavior was not completely controlled since the subjects were independent from investigators during the eight weeks of the experiment. However, reported dietary records and subsequent analyses showed that subjects in the CON, HPE and EXO groups consumed approximately 2,000-2,100, 1,800-1,900 and 1,700-1,800 kcal, respectively. And these values were not statistically different. The proportional composition of the dietary intake was 65:17:28, 58:32:10 and 70:15:15 for carbohydrates, protein and fat in the CON, HPE and EXO groups, respectively.

3. Changes in Physical Fitness

After the 8-week exercise program, no changes in any fitness parameters were observed except agility (Table 3). Subjects in the HPE and EXO groups showed an improved agility score in the 4th and 8th weeks of the experiment, and these were higher than the corresponding values for the CON group ($p<0.05$).

4. Changes in Blood Lipids and Glucose

Compared to baseline, TC level decreased in the HPE group (Table 4). The TC values in the baseline and 8th week were lower than those for the CON and EXO groups ($p<0.05$). When the absolute magnitude of changes

Table 3. Changes of Physical Fitness Parameters during the Experiment

Fitness Parameter	Week	Group		
		CON	HPE	EXO
Muscular Strength (Lower Back Strength)	0	50.6±11.0	46.9±13.9	51.0±15.0
	4	51.1±11.0	52.3±15.0	49.3±9.3
	8	50.3±9.2	53.5±15.2	51.0±14.0
Muscular Strength (Grip Strength)	0	22.3±4.3	21.8±3.5	23.8±4.0
	4	22.6±4.4	24.2±4.6	23.4±4.3
	8	23.4±4.8	23.2±4.1	23.2±5.3
Muscular Endurance (Sit-Up)	0	17.5±6.5	14.6±4.1	16.1±3.7
	4	18.4±6.5	16.0±3.3	15.9±3.2
	8	18.8±5.9	16.5±1.1	16.4±4.2
Agility (Side-Step)	0	28.3±3.3	28.0±6.2	29.4±10.1
	4	29.1±2.7	31.3±6.4*[a]	31.9±7.1*[a]
	8	28.9±4.5	32.4±5.3*[a]	33.0±8.8*[a]
Flexibility (Sit-and-Reach)	0	12.8±3.9	15.6±6.8	14.7±8.8
	4	13.7±3.4	17.5±6.6	16.6±7.7
	8	12.7±4.9	18.2±6.6	17.2±7.3

HPE: high protein diet and exercise participation group;
EXO: exercise participation only group; CON: control group;
* Significantly different compared to the 0 week at $p<0.05$
[a] Significantly different compared to the same testing period of group CON at $p<0.05$

(baseline minus 8th week) was compared among groups, the HPE group (13.1±5.6) showed a higher value than the CON (-4.1±6.5) and EXO (-2.3±18.5 mg/dL) (p<0.05). HDL-C level in the HPE group increased from the baseline in the 8th week (p<0.05). LDL-C level was lower in the HPE group than in the EXO group (p<0.05). Glucose level was lower in the 8th week in the HPE group than the baseline (p<0.05). No other changes were observed in TG level.

Table 4. Changes of Blood Lipids and Glucose Levels

Variables	Week	Group		
		CON	HPE	EXO
Serum Total Cholesterol	0	172.1±38.0	167.7±19.8[c]	187.9±48.2
	8	175.7±37.0	154.6±18.1*[ac]	190.1±43.3
High-Density Lipoprotein-Cholesterol	0	59.7±13.3	57.3±9.5	56.6±17.8
	8	59.9±13.5	60.6±9.2*	59.6±18.2
Low-Density Lipoprotein -Cholesterol	0	97.0±32.5	94.7±17.9	111.9±34.7
	8	100.3±29.7	79.7±14.8[c]	113.7±32.1
Triglycerides	0	74.9±23.1	78.4±37.2	97.1±20.7
	8	79.4±19.2	71.6±37.6	84.4±21.0
Glucose	0	87.1±8.3	96.1±9.0	92.7±7.8
	8	86.9±8.2	86.7±7.6*	90.0±6.9

Values: mg/dL
* Significantly different compared to the 0 week at p<0.05
[a, c] Significantly different compared to the same testing period of group CON and EXO, respectively, at p<0.05

DISCUSSION

Although an acute caloric restriction results in short-term body weight reduction, participation in regular aerobic exercise is known to contribute to gradual body weight reduction. And inclusion of exercise in a weight-control program normally has the advantage of minimizing repetitive weight gain.[8] Thus, combined applications of diet and exercise are highly recommended by most health professionals.

The present study demonstrated that the combined application of modified dietary composition such as a 25% high-protein diet and exercise led to a significant decrease in body fat and body weight compared to those who did not undertake such a program. In addition, although statistical differences were not observed, the effect of a combined high-protein diet and exercise program was more marginal than an exercise-only program. While no explanation could be found, it was postulated that an 8-week program was not long enough to induce obvious changes between the two groups.

A unique aspect of this study was the adaptation of usual energy intake for each subject solely through the modification of the protein content in her diet. High-protein diets have been criticized since changes in protein intake may simply reduce overall energy intake, thus causing weight reduction.[8] Also, dietary protein exerts a potent effect on satiety, thus inhibiting energy intake.[25] When delivered in iso-energetic amounts, high-protein meals generate stronger satiety than high carbohydrate or fat meals.[26] Due to these complications, we isolated the effects of energy deficit and subsequently assumed we were observing the sole effect of a high-protein diet. Luscombe *et al.*[27] failed to find that an increased protein diet enhanced weight loss or energy expenditure in subjects whose energy intake was restricted. In contrast, a hypocaloric diet with high-protein intake decreased body fat more than a hypocaloric diet alone, while body weight reduction was similar.[28] Recently, Wsterterp-Plantenga *et al.*[29] reported that a high-protein diet after a weight-loss program resulted in more favorable outcomes in terms of regaining weight such as no regaining of fat mass and slower regaining of weight. Skov *et al.*[18] reported greater weight and body fat reduction in subjects on a high-protein diet (25% of total energy) than those on a low-protein diet (12%). It has been proposed that desirable changes in body composition in subjects on a high-protein diet were due to improved nitrogen retention and overall anti-catabolic effects.[28]

Along the same lines, changes in body composition and a high-protein diet contributed to energy expenditure such as diet-induced thermogenesis.[27,30] Although we did not measure energy expenditure in this study, variations of body composition according to protein content variation were consistent with the results of previous studies.

In the present study, exercise was also effective in reducing body weight. Ross *et al.*[19] have shown that increased energy expenditure through exercise alone with energy intake remaining constant resulted in weight loss that was comparable to that derived from the equivalent amount of caloric deficit by energy intake. The results of the present study were consistent with that result since subjects in the high-protein diet and exercise group as well as those in the exercise-only group lost weight. Those in the control group did not. Also, aerobic exercise over the 8-week period led to an improvement in some fitness parameters such as aerobic exercise capacity and agility. Often, it has been reported that cardiorespiratory endurance may increase in this time period, especially in those who have not participated in exercise programs before.

The relationship between protein supplementation and muscular strength has been reported.[28] Investigators found an increase in muscular strength in police officers on a program involving a moderate hypocaloric, high-protein diet and resistance training. However, we did not observe any changes in muscular strength parameters in those on the high-protein diet and/or exercise programs. The different outcomes may be a result of the modes of exercise used and the subjects involved.

Although some of the blood parameters showed changes by the end of the experiment, previous studies reported inconsistent results for subjects on high-protein diets.[17,18,31,32) Soybean protein consumption contributed to cardiovascular disease prevention[33) and had a positive effect on blood lipoprotein profiles. In general, the present study showed favorable changes in blood lipids. However, as other investigators have suggested, the length of the experimental program, the nature of the protein diet, the exercise volume, and the subject's status and dieting habits may contribute to varying results.

While the results of the present study offer some insight into the effects of a high-protein diet on changes in body weight, some limitations exist. Although we carefully controlled our subjects, their dietary intake and composition were not as closely managed as we had planned. For these reasons, we only reported the values for their dietary caloric intake in terms of range rather than means. And the proportion of their dietary protein intake was above the targeted value, such as the 32% in the high-protein diet group. However, from a practical point of view, it has to be remembered that protein-intake levels must be controlled not only by health professionals but by the subjects themselves.

CONCLUSION

Although the results for the exercise-only group were similar to those for the high-protein diet and exercise group, the favorable changes in body weight, body composition and blood lipid, as well as improvements in aerobic capacity, were more marginal in the latter group.

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