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Effectiveness of a soy-based compared with a traditional low-calorie diet on weight loss and lipid levels in overweight adults

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Abstract

Objective: This study investigated the effects of a soy-based low-calorie diet on weight control, body composition, and blood lipid profiles compared with a traditional low-calorie diet.

Methods: Thirty obese adults (mean body mass index 29–30 kg/m^2) were randomized to two groups. The soy-based low-calorie group consumed soy protein as the only protein source, and the traditional low-calorie group consumed two-thirds animal protein and the rest plant protein in a 1200 kcal/d diet for 8 wk. A diet record was kept everyday throughout the study. Food intake was analyzed before and after the study. Anthropometric data were acquired every week, and biochemical data from before and after the 8-wk experiment were compared.

Results: Body weight, body mass index, body fat percentage, and waist circumference significantly decreased in both groups ($P < 0.05$). The decrease in body fat percentage in the soy group (2.2%, 95% confidence interval 1.6–2.8) was greater than that in the traditional group (1.4%, 95% confidence interval −0.1 to 2.8). Serum total cholesterol concentrations, low-density lipoprotein cholesterol concentrations, and liver function parameters decreased in the soy-based group and were significantly different from measurements in the traditional group ($P < 0.05$). No significant change in serum triacylglycerol levels, serum high-density lipoprotein cholesterol levels, and fasting glucose levels was found in the soy or traditional group.

Conclusion: Soy-based low-calorie diets significantly decreased serum total cholesterol and low-density lipoprotein cholesterol concentrations and had a greater effect on reducing body fat percentage than traditional low-calorie diets. Thus, soy-based diets have health benefits in reducing weight and blood lipids.

Keywords: Soy; Obesity; Body fat percentage; Serum cholesterol; Weight loss

Introduction

The prevalence of overweight and obesity worldwide has dramatically increased in recent decades [1]. Compelling evidence has linked obesity not only to various chronic diseases, such as diabetes mellitus, heart disease, hypertension, stroke, cholecystolithiasis, and gout, but also to cancer, including colorectal and breast cancers [2,3]. In 1996, the World Health Organization and the Food and Agriculture Organization announced that obesity can be regarded as a chronic disease and emphasized the importance of maintaining an ideal body weight. According to results from a survey in Taiwan in 1998 [4], nearly 25% of adults are overweight. This report indicates that obesity has become a serious public health problem in Taiwan. Energy imbalance, i.e., energy intake higher than energy expenditure, is the main reason for people becoming overweight and obese. Dietary patterns are closely related to obesity [5,6].

Soy contains abundant nutrients and is a common component of the traditional Chinese diet. Soybean proteins are used in a variety of forms, including infant formulas, flours, protein isolates and concentrates, and textured fibers. Soy-containing foods include cheese, drinks, miso, tempeh, tofu, salami, and vegetarian meat substitutes. It has been shown that a soy-based diet has a weight-loss effect and can pre-

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vent obesity because soy is rich in dietary fiber, thereby increasing satiety [7], and that a soy-based meal helps to decrease fat mass [8]. Further, soy peptide seems to improve the thermic response of brown adipose tissue and thus may be a useful treatment option for obesity [9,10]. However, those findings were based on animal studies, and no clinical studies have examined the results of a weight-loss program using soy products for obese people. The effectiveness of soy products on weight loss is still unclear [11]. Therefore, this study investigated the effects of a soy-based diet on weight management and body composition. The results of this study will be applied to clinical therapies for the overweight and obese and to decrease morbidity associated with obesity.

Materials and methods

Subjects

This study was carried out at Taipei Medical University. Flyers and leaflets were used to recruit 30 volunteers (6 men and 24 women) before the experiment's start date. Subjects had to be 20–60 y of age, have a body mass index (BMI) >26 kg/m^2, and have no history of chronic disease, including cardiovascular disease, kidney disease, and diabetes mellitus. Female subjects could not be pregnant or breastfeeding. All subjects submitted written informed consent before their participation. The guidelines and procedures were approved by the research ethics committee of Taipei Medical University, Taiwan.

Study design

Subjects were randomly allocated to two groups: a traditional group (traditional low-calorie diet) and a soy group (soy low-calorie diet). The soy group consumed soy protein as the only protein source, and we provided various soy foods, including drinks, miso, tofu, and vegetarian meat substitutes, from markets. Each subject in the soy group received a meal box for every lunch and dinner for 8 wk. Two-thirds of the protein for the traditional group was animal protein, and the rest was plant protein. Table 1 lists differences in the prescribed diet content for each group. We also educated participants on the dietary guidelines for 1200-kcal diets and clarified the concepts of protein sources and food portions. A meal plan was given to subjects in the traditional group, but no prepared food. Both groups were given lectures on weight management at each visit. A diet record was kept everyday throughout the study. Food intake records were analyzed using Nutritionist Pro 1.0 (E-Kitchen Business Corp., Taiwan). Thirty subjects completed the study. Anthropometric measurements including height, weight, blood pressure, and body composition were weekly measured. Biochemical parameters were analyzed at the beginning and the end of the intervention. Side effects including gastrointestinal symptoms, effects on skin, hair, and bone, and physical activity were evaluated.

Table 1
Contents of the prescribed diet for each group

Nutrient content/group	Soy group*	Traditional group†
Total energy (kcal)	1200	1200
Carbohydrates (60%)	180 g	180 g
Lipids (25%)	33 g	33 g
Protein (15%)	45 g	45 g
Animal protein	0	30 g
Soy protein	45 g	15 g

* Soy products were the main protein source in the soy group.
† Two-thirds of the protein of the traditional group was from animals, and one-third was from plant proteins.

Anthropometric measurements

The height of each subject was measured with a stadiometer. Body composition including body weight and body fat percentage were determined with the InBody 3.0 Body Composition Analyzer (InBody 3.0, Biospace, Seoul, Korea), which uses an 8-point tactile electrode system that measures the total and segmental impedance and phase angle of alternating electric current at four different frequencies. It was used according to the manufacturer's instructions. The accuracy of this measurement to assess percentage of body fat was reported by many researchers [12]. Subjects took a rest for $\geq$30 min before measurement. Then subjects took off excess clothing (coats, sweaters), shoes, and socks, stood on the four foot-electrodes on the instrument's platform and held the two palm-and-thumb electrodes with the arms not touching the torso. Each subject's height and age were entered, and the body composition data were calculated by the device's software and immediately printed on the paper obtained from the manufacturer. Waist circumference was measured with an inelastic scale.

Blood pressure

Blood pressure was measured on the subject's right arm with a mercury sphygmomanometer by trained personnel who confirmed and pressed the pulse before the measurement.

Biochemical measurements

Venous blood samples were collected at the beginning and the end of the intervention for analysis of serum glucose, triacylglycerols, total cholesterol, high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), glutamate oxaloacetate transaminase, and glutamate pyruvate transaminase. Blood samples were drawn after overnight fasting and immediately centrifuged. Blood biochemical parameters were measured at the laboratory of Taipei Medical University Hospital. Serum total cholesterol, triacylglycerols, HDL-C, glutamate oxaloacetate transaminase, and glutamate pyruvate transaminase were determined by enzymatic methods [13–15]. The LDL-C concentration was calculated using Friedewald's formula [16]. The plasma glucose concentration was measured using the glucose oxidase method.

Statistical analysis

All data were presented as mean ± standard deviation. Differences between the beginning and the end of treatment were tested with paired *t* test. We used Student's *t* test to compare differences between the traditional group and the soy group. SPSS 10.0 for Windows (SPSS, Inc., Chicago, IL, USA) was used to analyze the data. $P < 0.05$ indicated statistical significance.

Results

Thirty subjects (6 men and 24 women) completed the 8-wk intervention study. Fifteen subjects (3 men and 12 women) were assigned to the soy group and 15 subjects (3 men and 12 women) consumed the traditional low-calorie diet. Baseline subject characteristics were similar between groups except age. The traditional group was older than the soy group but there was no significant difference. The initial BMI of subjects given the soy low-calorie diet was 29.6 ± 3.0 kg/m^2, and the initial body weight was 76.2 ± 14.1 kg. The initial BMI of subjects given the traditional low-calorie diet was 30.0 ± 3.9 kg/m^2, and the initial body weight was 77.6 ± 16.9 kg. There was no significant difference in the characteristics of the two groups at the beginning of the study (Table 2). No adverse events occurred at the end of the intervention.

Both low-calorie diets significantly reduced body weight, BMI, and body fat percentage ($P < 0.05$) over 8 wk (Table 2). Body fat percentage losses for subjects at 8 wk were 2.2% of initial body weight (95% confidence interval 1.6–2.8) in the soy group and 1.4% (95% confidence interval −0.1 to 2.8%) in the traditional group. The BMI of the soy group decreased by an average of 0.2 kg/m^2 per week, and the total decrease was 1.6 kg/m^2 ($P < 0.05$). The soy group and the traditional group were not significantly different in waist circumference or blood pressure after 8 wk.

After the intervention, the soy group had significantly lower levels of serum total cholesterol, serum LDL-C, glutamate oxaloacetate transaminase, and glutamate pyruvate transaminase than the traditional group ($P < 0.05$). After the 8-wk program, the soy group had significantly decreased levels of serum total cholesterol and serum LDL-C ($P < 0.05$), whereas the traditional group had significantly decreased serum total cholesterol levels ($P < 0.05$). Neither group had any significant change in serum HDL-C levels (Table 3). The HDL-C/total cholesterol ratio of the soy group was slightly higher than that of the traditional group after 8 wk. Serum triacylglycerol and fasting glucose levels had decreased slightly in both groups after weight reduction, but there was no significant difference between the two groups.

In the soy group, caloric and carbohydrate intakes significantly differed between the initial and final periods, whereas protein, fat, and dietary fiber intake did not (Table 4). These data indicated that subjects appeared to accept the low-calorie diets of the program.

Discussion

In this study, the effectiveness of weight loss in the soy low-calorie diet group was similar to that in the traditional low-calorie diet group, whereas the body fat percentage of the soy group significantly decreased compared with that of the traditional group. Both groups showed significant decreases in body weight of an average of 0.6 kg/wk, which is within the suggested ideal weight loss rate of 0.5–1 kg/wk [17,18]. Maskarinec et al. [19] showed that having beans in the diet, including legumes, tofu, and soy products, was negatively related to BMI after adjustment for daily energy intake. A very low-energy diet containing soy [20] or a high-soy-protein diet [21] may be better at maintaining nitrogen balance and reducing body fat by preventing further increase in protein breakdown in healthy obese people.

Table 2
Anthropometric measurements and changes before and after the weight-loss program*

	Soy group			Traditional group		
	Beginning	End	Change	Beginning	End	Change
Age (y)	28.8 ± 9.1			38.0 ± 11.1		
Height (cm)	159.8 ± 7.4			160.1 ± 7.4		
Body weight (kg)	76.2 ± 14.1	72.2 ± 13.3[a]	−4.0 ± 1.7	77.6 ± 16.9	73.7 ± 14.8[a]	−3.9 ± 3.3
Body mass index (kg/m^2)	29.6 ± 3.0	28.1 ± 2.9[a]	−1.6 ± 0.6	30.0 ± 3.9	28.5 ± 3.5[a]	−1.5 ± 1.2
Body fat (%)	39.2 ± 3.7	36.9 ± 3.3[a]	−2.2 ± 0.9	36.9 ± 4.4	35.5 ± 5.8[a]	−1.4 ± 2.2
Waist circumference (cm)	87.3 ± 11.0	84.8 ± 10.3[a]	−2.5 ± 3.5	90.2 ± 13.7	87.3 ± 12.3[a]	−2.9 ± 3.3
Systolic pressure (mmHg)	111.1 ± 12.1	114.0 ± 9.5	2.9 ± 6.1	114.0 ± 16.7	115.6 ± 12.2	1.6 ± 11.7
Diastolic pressure (mmHg)	74.0 ± 9.4	73.8 ± 6.7	−0.2 ± 8.5	79.0 ± 9.2	74.0 ± 9.8	−5.0 ± 10.5

* Data are presented as mean ± SD (n = 15/group). Mean values within a row with superscript letters were significantly different between before and after the intervention by using paired t test ($P < 0.05$).

Table 3
Biochemical data and changes before and after the weight-loss program*

	Soy group			Traditional group		
	Beginning	End	Change	Beginning	End	Change
TC (mg/dL)	173.1 ± 18.0	149.4 ± 21.6†	−23.7 ± 15.7	183.1 ± 22.8	164.8 ± 29.0†‡	−18 ± 18.0
TG (mg/dL)	89.9 ± 33.7	80.1 ± 31.0	−9.8 ± 35.4	102.0 ± 47.1	80.2 ± 32.5	−21.8 ± 46.2
LDL-C (mg/dL)	110.6 ± 17.0	95.1 ± 16.2†	−15.4 ± 7.7	119.4 ± 15.7	110.4 ± 20.6‡	−9.0 ± 16.5
HDL-C (mg/dL)	44.1 ± 4.9	43.3 ± 10.9	−0.8 ± 11.7	47.2 ± 12.2	45.2 ± 10.0	−2.0 ± 4.9
HDL-C /TC	0.26 ± 0.04	0.31 ± 0.10	0.04 ± 0.10	0.26 ± 0.04	0.27 ± 0.02	0.02 ± 0.04
GOT (IU/L)	17.8 ± 2.0	15.8 ± 2.3	−2.0 ± 2.4	21.9 ± 9.8	22.6 ± 8.9‡	0.7 ± 10.0
GPT (IU/L)	17.6 ± 4.7	13.6 ± 4.6	−4.0 ± 4.0	18.9 ± 8.4	19.3 ± 9.0‡	1.3 ± 4.3
Glucose (mg/dL)	100.8 ± 9.8	97.9 ± 6.2	−2.9 ± 5.0	104.9 ± 17.5	97.1 ± 7.4	−7.8 ± 19.4

GOT, glutamate oxaloacetate transaminase; GPT, glutamate pyruvate transaminase; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol; TG, triacylglycerols

* Data are presented as mean ± SD (n = 15/group).

† Values within a row were significantly different between before and after the intervention by using paired t test ($P < 0.05$).

‡ Values within a row were significantly different between the soy-based low-calorie diet and the traditional low-calorie diet by using t test ($P < 0.05$).

Moreover, replacement of animal protein in the diet with soybean protein has been reported to reduce weight and improve lipid metabolism. Anderson and Hoie [22] reported that obese and hypercholesterolemic subjects using a commercial soy-based liquid meal replacement had significant reductions in weight, although using milk meal replacement did not reduce weight for 12 wk, and soy-based diets led to greater reduction in serum cholesterol and LDL-C levels than milk-based diets. These investigators also considered that a soy diet might promote faster weight loss than a meal replacement and an energy-restricted (>1500 kcal/d) diet over the first 8 wk [23]. In another clinical study, 11 obese women were provided with a diet of 1000 kcal/d over 12 wk in which a soy-based or a milk-based liquid formula replaced two regular meals. The soy-based diet reduced serum cholesterol by 20% from the initial level, whereas no effect was seen with the milk diet [24]. Allison et al. [8] reported that a soy-based meal replacement formula of 1200 kcal/d was effective in not only lowering body weight and fat mass but also reducing LDL-C in obese subjects over 12 wk, which agrees with our study findings. In our study, body fat percentage, serum cholesterol levels, LDL-C levels, and liver function parameters decreased more in those on a soy-based diet than those on a traditional low-calorie diet. Therefore, we suggest that soy as the major protein source may be beneficial for weight loss.

The capacity of soy protein to regulate weight and lipid metabolism might be explained by its amino acid constitution and other ingredients. In comparison with most other legumes, soybean contains a high percentage of protein, higher absolute amounts of dispensable amino acids such as arginine, glycine, and alanine, and a high percentage of isoflavones including genistein and daidzein. Recent research indicates that soy protein reduces the expression of sterol regulatory element binding protein-1 [25], which inhibits lipid accumulation and the expression of lipogenic genes, resulting in the reduction in body fat to the degree seen in subjects in this study. Aoyama et al. [26] found that the body fat content in obese rats fed energy-restricted diets with soy protein isolate, 90% protein based on dry weight and the most concentrated form of soy protein, and its hydrolysate was significantly lower than that in those fed a casein diet. In hypercholesterolemic individuals, isolated soy protein distinctly modulates the fractional synthesis rates of triacylglycerol fatty acids and free cholesterol and reduces circulating triacylglycerol and cholesterol levels [27]. In addition, soy isoflavones stimulate sterol regulatory element binding protein-2, increasing serum cholesterol clearance [28], and soy-based diets with high or low isoflavone content affect several mechanisms to regulate lipid oxidation and peroxisome proliferator-activated receptor activation [29]. Those studies showed that the constitution of soy foods is a key to the regulation of lipid metabolism, and thus soy consumption can improve blood lipid profiles. However, it is critical to show that single components or complex components of soy are associated with lipid metabolism. In this study, by using many soy foods common at the market in Taiwan, including drinks, miso, tofu, salami, and vegetarian meat substitutes, we found significant reductions in body fat percentage and blood lipid profiles. Therefore, intake of different soy foods might regulate lipid accumulation and metabolism because of their complex ingredients.

Table 4
Energy and macronutrient intake at the beginning and end of the weight-loss program*

	Soy group		Traditional group	
	Beginning	End	Beginning	End
Calories (kcal/d)	1256 ± 126	1156 ± 165[a]	1218 ± 52	1229 ± 15
Carbohydrate (g/d)	179 ± 23	164 ± 26[a]	181 ± 13	165 ± 21
Protein (g/d)	44 ± 6	42 ± 6	48 ± 8	45 ± 5
Fat (g/d)	40 ± 7	37 ± 7	34 ± 9	41 ± 8
Fiber (g/d)	7.8 ± 1.8	6.6 ± 0.9	8.8 ± 2.6	7.6 ± 1.1

* Data are presented as the mean ± SD (n = 15/group). Values within a row with superscript letters were significantly different between before and after the intervention by using paired t test ($P < 0.05$).

In addition, promoting satiation and altering secretion of gut hormones are mechanisms by which soy foods are involved in weight loss. Lang et al. [30] compared soy, egg albumin, gelatin, pea protein, and wheat gluten in six lunches, and no effect was seen on 24-h food intake or satiety. However, in a comparison by Anderson and colleagues [31] of a combination of sucrose and 45 g of soy protein with egg albumin or casein, satiety was increased after soy and sucrose consumption. The complex carbohydrates and dietary fiber contained in soy take longer to pass through the gastrointestinal system and have low glycemic indexes [32], which is beneficial for weight control [10]. McLaughlin et al. [33] proposed that trypsin inhibitors in soy reduce food intake and stimulate cholecystokinin release, increasing satiety, and that is the reason for soybeans' association with weight control. Other studies have shown that the special structures or amino acid sequences of soy protein act directly on rat small intestinal mucosal cells to stimulate cholecystokinin release [34], readily inducing satiety. In our data we found that the soy group had a significant reduction in calorie intake; the soy protein may have been more satiating.

Soy serves as a source of good-quality protein for humans. Consumption of soy foods is increasing because of the reported benefits for nutrition and health [35,36]. Soy-based meal replacement formulae improve weight reduction, anthropometric profile, serum lipids, and blood pressure for obese adults during caloric restriction [37]. In addition, a high-soy-protein diet can improve glycemic control in overweight and obese people [23]. Soy protein may protect the obese against obesity-linked renal disease and metabolic syndrome [29,38]. According to a follow-up study, soy protein is a suitable protein source in energy-restricted diets for the treatment of obesity and may lower some risk factors (including hypertension, hyperlipidemia, and hyperglycosemia) for chronic disease in obese people.

In conclusion, a weight-loss diet containing high-quality soy products as the main source of protein reduced not only the body fat percentage but also serum total cholesterol and LDL-C concentrations, and could improve hyperlipidemia associated with obesity during a weight-loss program.

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