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Original studies

Changes in anthropometric measurements, body composition, blood pressure, lipid profile, and testosterone in patients participating in a low-energy dietary intervention

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Abstract

Objective: The purpose of this study was to describe changes in anthropometric measurements, body composition, blood pressure, lipid profile, and testosterone following a low–energy-density dietary intervention plus regimented supplementation program.

Methods: The study design was a pre-post intervention design without a control group. Normal participants were recruited from the faculty, staff, students, and community members from a chiropractic college to participate in a 21-day weight loss program. All participants (n = 49; 36 women, 13 men; 31 ± 10.3 years of age) received freshly prepared mostly vegan meals (breakfast, lunch, and dinner) that included 1200 to 1400 daily calories (5020.8 to 5857.6 J) for the women and 1600 to 1800 (6694.4 to 7531.2 J) daily calories for the men. Nutritional supplements containing enzymes that were intended to facilitate digestion, reduce cholesterol levels, increase metabolic rate, and mediate inflammatory processes were consumed 30 minutes before each meal. The regimented supplementation program included once-daily supplementation with a green drink that contained alfalfa, wheatgrass, apple cider vinegar, and fulvic acid throughout the study period. A cleanse supplementation containing magnesium, chia, flaxseed, lemon, camu camu, cat's claw, bentonite clay, tumeric, pau d'arco, chanca piedra, stevia, zeolite clay, slippery elm, garlic, ginger, peppermint, aloe, citrus bioflavonoids, and fulvic acid was added before each meal during week 2. During week 3, the cleanse supplementation was replaced with probiotic and prebiotic supplementation.

Results: Multiple paired *t* tests detected clinically meaningful reductions in weight (−8.7 ± 5.54 lb) (−3.9 ± 2.5 kg), total cholesterol (−30.0 ± 29.77 mg/dL), and low-density lipoprotein cholesterol (−21.0 ± 25.20 mg/dL) ($P < .05$). There was a pre-post intervention increase in testosterone for men (111.0 ± 121.13 ng/dL, $P < .05$).

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Conclusions: Weight loss and improvements in total cholesterol and low-density lipoprotein cholesterol levels occurred after a low–energy-density dietary intervention plus regimented supplementation program.
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Introduction

The prevalence of obesity has increased from 11.9% to 33.4% in men and from 16.6% to 36.5% in women when comparing the National Health and Nutrition Examination Survey I study (1971-1975) to the National Health and Nutrition Examination Survey 2005-2006 data.[1] As summarized by Rolls,[2,3] the accumulating evidence suggests that the promotion of diets that reduce the energy density of foods consumed and address the effects of portion size on the intake of nutritious low-energy dense foods may be an effective future strategy to both prevent and treat obesity. Epidemiological evidence substantiates that consumption of low–energy-density carbohydrates, for example, fruits, vegetables, and whole grain products, positively impacts weight and health even though clinical trials evidence may be lagging.[4] Low–energy-density diets may allow individuals to more effectively lose weight, maintain a healthy weight, and prevent chronic diseases associated with being overweight and obese to include cardiovascular disease, type II diabetes, and certain types of cancers.[4-8] In addition, portion size provides independent and additive effects of energy density on weight management; and portion size impacts energy intake for a single meal with the potential for persistent effects on energy intake over multiple days.[cf3]

Research on vegetarian diets, especially vegan diet, and the Mediterranean-style diets provides us with good examples of the impact of consuming nutritious low-energy dense foods on weight and health.[9-14] Given that adherence to the diet plan is the critical factor for weight loss, weight maintenance, and health benefits, health care professionals need to address individualized eating habits of patients, the effectiveness of popular weight loss diets, and the cost of purchasing of foods when making dietary recommendations.[15,16] However, designing energy (calorie)-restricted diet plans based upon the consumption of low–calorie-density foods may be able to overcome the adherence barriers of patient behaviors and dietary costs. Patient education is emerging as an effective strategy associated with individuals consuming reduced-calorie diets.[17-20] Preliminary data on the dietary costs of nutritious low-calorie dense foods are beginning to indicate their affordability.[21-23] Other research is emphasizing the importance of addressing the effects of food costs on implementing nutritional interventions for the consumption of healthy foods and the resultant impact on reducing obesity and disease-related risk factors.[24-26]

In addition to dietary modifications, emerging evidence suggests a relationship between the microbial ecology of the gut and obesity.[27-29] Recommendations for dietary interventions with probiotic and prebiotic nutritional components suggest that alleviating dysbiosis, an imbalance of intestinal bacteria and/or elevated levels of fungi, may restore the optimal microbial ecology of the gut.[29-33] Probiotics and prebiotics may have significant health benefits on lipid metabolism, mineral absorption, and immune function via their beneficial influences on microbial ecology of the gut.[29,31-35] Although there are limited clinical data on the role of microflora management interventions on weight loss and improved health status,[36-38] probiotic and prebiotic nutritional supplementation and colon cleansing products are being promoted as critical elements for initiating and maintaining weight loss. Probiotic and prebiotic nutritional supplements may evolve into a daily regimen to maintain optimal microbial ecology of the gut for weight management and health.[31,32] To date, colon-cleansing products lack sufficient evidence; but anecdotal recommendations suggest using colon-cleansing products as a detoxification intervention once or twice a year.

In systematic reviews and meta-analyses, dietary modifications involving either low-carbohydrate foods or low-fat diets induce weight loss and reduce metabolic risk factors.[9-14,39] These data suggest that low–calorie-density diets and caloric restriction may be the critical elements in weight management programs regardless of dietary macronutrients.[2,3,15] Designing and describing calorie-restricted meal plans of low–calorie-density foods may help health care professions address the constraints of time, knowledge, and costs of promoting and/or delivering nutritional interventions as well as providing their patients with meal plans that fit

their lifestyle, nutritional preferences or eating habits, and economic status. Another component of weight management programs is the use of nutritional supplements. However, the use of nutritional supplements with and without dietary modifications to facilitate weight loss and reduce metabolic risk factors is lacking sufficient evidence.[40] Theories suggesting a relationship among the microbial ecology of the gut, weight management, and health indicate an adjunct role for supplementation in the presence of low–calorie-density foods.[27-29] Thus, in the current study, a low–calorie-density dietary intervention with patient education was used to address various physiologic and behavioral aspects contributing to the development of a positive calorie balance that leads to weight gain,[2,3,18] whereas the inclusion of nutritional supplementation was used to target the potential role of gut microbiota in obesity.[31,32]

The purpose of the study was to describe changes in anthropometric measurements, body composition, blood pressure, lipid profile, and testosterone following a low–calorie-density dietary intervention plus regimented supplementation program with patient education (21-day treatment intervention program). The selected outcome measures are some parameters used to determine if a patient meets the diagnostic criteria for metabolic syndrome, which increases the risk of cardiovascular disease, stroke, and type II diabetes.[41]

Methods

Recruitment and study design

Using a convenience sampling technique, men and women were recruited from faculty, staff, students, and community members at a professional school (20-60 years of age). Participants were recruited by making announcements in class with the permission of the class instructor. The principal investigator also personally contacted members of the faculty and staff who had expressed an interest in nutritional studies conducted at the college. The study design was an observational, pre-post intervention without a control group or blinding (n = 50). A sample size of 50 participants was estimated to detect a weight loss of 8 lb (3.6 kg) and pre-post differences of 20 mg/dL for total cholesterol and low-density lipoproteins at 90% power and a significance level of .05 using paired *t* test statistical analyses. All 50 participants participated in the 21-day treatment intervention program (36 women and 14 men). Outcome assessments were performed at baseline (preintervention) and after the 21-day treatment intervention (postintervention). The New York Chiropractic College Institutional Review Board approved all measurement and intervention procedures for the study. All participants provided written informed consent.

Exclusion criteria

Individuals that were pregnant; were nursing; had a pacemaker; and were on medications for hypertension (such as a diuretic, angiotensin-converting enzyme inhibitor, or calcium channel blocker), cholesterol (such as a statin drug), or diabetes (such as metformin) were excluded from the study. Individuals with any food allergy or with known allergies to any of the supplement ingredients were excluded. Individuals with any digestive disorders such as Crohn disease or ulcerative colitis as well as individuals who had undergone any surgery to the gastrointestinal system including, but not limited to, hiatal hernia surgery, bariatric surgery, lap band, and/or colostomy were excluded. Individuals with any diagnosed blood disorder including, but not limited to, anemia, low platelet count and clotting disorder were excluded. In summary, individuals on any prescribed medications, except birth control pills, over-the-counter medications, vitamins, or supplements, were excluded.

In addition, screenings of blood pressure and body mass index (BMI) occurred at the first laboratory visit. Measurements of sitting blood pressure were from both arms using the standard clinic procedure of mercury sphygmomanometer with the Korotkoff sound technique according to the recommendations for blood pressure measurements in humans.[42] The exclusion criteria used for blood pressure were a systolic blood pressure of at least 150 mm Hg and/or diastolic blood pressure of at least 95 mm Hg. Participants were allowed to participate with mild unmedicated hypertension (>140/90 mm Hg) because of the potential effects of the 21-day intervention program on reducing blood pressure associated with weight loss and improvements in lipid profiles. Blood pressure was measured at the postintervention laboratory visit both as an outcome measure and to advise participants on their current blood pressure status. Participants with a calculated BMI of less than 20 kg/m^2 were excluded for being underweight (cf anthropometric measurements below).

Twenty-one-day treatment intervention program

All participants received prepared meals for 21 days, delivered every day or every other day, and on Fridays for the weekends. The company supplying the food (5 Squares, New Rochelle, NY) provided food, local and organic when available; and the menu was predominately vegan after the first few days. Meal plan and recipes are available upon request from the principal investigator. The low–calorie-density diet had on average 1200 to 1400 daily calories (5020.8 to 5857.6 J) for the female participants and 1600 to 1800 daily calories (5594.4 to 7531.2 J) for the male participants. Participants were instructed to maintain their normal amount of daily physical activities and not to engage in exercise beyond 20 minutes of walking, yoga, or tai chi.

The regimented supplementation program was divided into 3 weekly phases: Reclaim, Release, and Restore (Ultimate Reset Beachbody, Santa Monica, CA). The regimented supplementation program is summarized below.

The supplementation regimen during the Reclaim week (week 1) was as follows:

- Thirty minutes before breakfast, lunch, and dinner, participants drank 12 to 24 oz of distilled water (which was provided) with a "pinch" of Himalayan salt, consumed 10 to 15 drops of a liquid oxygen supplement, and swallowed 2 systemic enzyme capsules containing protease/bromelain, serrapeptase, papain, amylase, lipase, rutin, amla, maltosextrin, methylsulfonylmethane, and camu camu.
- At least 2 hours after lunch, participants drank 12 to 24 oz of distilled water with a "pinch" of Himalayan salt and another 4 to 8 oz of distilled water mixed with 3 g of alkalinizer powder ("green food": alfalfa, wheatgrass, apple cider vinegar, fulvic acid). After waiting 30 minutes, participants were allowed to consume a snack consisting of unsalted almonds and/or apples. The participants purchased these snack foods for themselves.
- The participants waited a minimum of 2 hours after consuming the alkalinizer supplement or snack to consume their dinner supplements (12-24 oz of distilled water with a "pinch" of Himalayan salt, liquid oxygen, and systemic enzymes). Then 30 minutes later, participants consumed their dinner.

During the Release week (week 2), the participants followed the same regimen as the Reclaim week (week 1). However, in addition to the Reclaim premeal regimen, participants drank 8 to 12 oz of distilled water mixed with 10 g of detoxify powder (magnesium, chia, flaxseed, lemon, camu camu, cat's claw, bentonite clay, tumeric, pau d'arco, chanca piedra, stevia, zeolite clay, slippery elm, garlic, ginger, peppermint, aloe, citrus bioflavonoids, and fulvic acid) 30 minutes before each meal.

During the Restore week (week 3), the participants followed the same regimen as the Reclaim week (week 1). However, in addition to the Reclaim premeal regime, participants swallowed 2 capsules of a prebiotic/probiotic supplement containing LactoSpore (*Bacillus coagulans*; Sabinsa, Payson, UT) and yacon 30 minutes before breakfast, lunch, and dinner. The prebiotic/probiotic supplement was added after the colon cleanse to enhance any potential impact of the prebiotic/probiotic agents on restoring optimal microbial ecology of the gut.

During the 21-day treatment intervention, participants were allowed to drink additional amounts of distilled water throughout the day and with their meals. Participants were asked to refrain from drinking other types of beverages including, but not limited to, coffee, tea, alcohol, soda, milk, or juice.

Data collection

Anthropometric measurements included body weight, height, BMI, and waist and hip circumferences. Anthropometric assessments were conducted with the participants wearing light clothing (gown and shorts) and barefoot. Weight was measured using a high-precision digital scale (DI-10, DIGI Matex, Inc, Singapore; 0.1-kg gradations, 225-kg capacity). Height was measured using a high-precision digital stadiometer (seca 242, Hamburg, Germany; 1-mm gradations; measuring range, 62-210 cm). Body mass index was calculated from the measured body weight and height (kilograms per square meter). A standard cloth tape measure was used to record waist and hip circumference in inches. The clinician measured the circumferences of each site at least 3 times and averaged the 3 most consistent measurements to enhance reliability. Body landmarks of the umbilicus and greater trochanters were used to standardize measurements of pre-post waist and hip circumferences, respectively, to enhance reliability and validity. The waist-to-hip ratio and waist-to-height ratio were calculated.

Body composition was estimated using bioelectrical impedance analysis (BIA) (Biomarkers 2000 Body Scan Analyzer, Biodynamics Corporation, Seattle, WA). The validity of BIA as compared with dual-

energy x-ray absorptiometry to estimate body composition exhibited high relative agreement in normal-weight, overweight, and obese individuals.[43-45] The regression analysis of BIA and dual-energy x-ray absorptiometry method to measure fat mass at baseline and then at 6 and 12 months after bariatric surgery in premenopausal morbidly obese women was 0.98, 0.94 and 0.99, respectively.[46] The Biomarkers 2000 device uses the wrist-ankle electrode arrangement, which is convenient, is easy to use, and yields accurate results for participants in the normal-weight, overweight, and obese categories relative to BMI or body fatness.[47-49]

Participants came to the laboratory after an overnight fast and 24 hours without exercising and consuming alcohol or stimulant beverages. The participants were lying supine on a stationary massage table (Earthlite, Vista, CA) in a relaxed position with their feet 12 to 18 in apart, their upper-inner thighs spread far enough apart so that they did not touch each other, their hands no more than 6 in from their sides, and their upper-inner arms not touching the torso. Electrodes (25 mm × 25 mm, Ag-Ag Cl, SilveRest, Bellows Falls, VT) were placed on the right hand and right foot according to the manufacturer's guidelines and the traditional supine arm-to-leg BIA method. Predictive models for total body water, fat mass, and fat-free mass (lean body mass) and their percentages, as well as percentages of intracellular water and extracellular water, were calculated from measurements of resistance and reactance values based on the preprogrammed algorithms accompanying the BIA instrument that incorporated the measured weight, height, sex, and age. Although measurement procedures for BIA met all standards to ensure accuracy, BIA only provides an estimate of body composition.[43,45,47,48]

Fasting lipid profile and testosterone were obtained from each participant pre-post diet intervention. Professional services were obtained from a local hospital to perform the blood draws and analyze the venous plasma samples. Venous plasma (lithium heparin) was collected by standard venipuncture technique from the antecubital vein. Venous plasma samples were analyzed using routine clinical chemistry methods to measure total cholesterol, low-density lipoproteins (LDL cholesterol), high-density lipoproteins (HDL cholesterol), triglycerides, and testosterone.

Statistical analyses

Pre-post intervention data from the anthropometric measurements, lipid profile, blood pressure, and body composition estimations were compared using paired *t* tests for each dependent variable. A sex by time mixed analysis of variance model was used to detect changes in testosterone pre-post intervention as a function of sex. Treatment integrity and adverse events were described qualitatively from the weekly diaries. Intention-to-treat analyses were used to account for participants that withdrew from participation. The level for each statistical procedure was 0.05. There was no correction for multiple dependent variables, for example, experiment-wise error rate.

Results

Study population

During a period of 1 week, we recruited 52 participants to participate in the research study. Two of these participants were excluded for having high blood pressure. The remaining 50 patients were enrolled into the research study. Upon completion of the preintervention blood analyses, 1 participant was withdrawn from the study by the principal investigator. Although this participant did not satisfy any exclusion criteria at the time of enrollment, an underlying medical condition was diagnosed from blood analyses; and the participant was appropriately referred for medical treatment. The preintervention data points for this participant were deemed outliers and excluded from the statistical analyses.

Six other participants dropped out of the study. One of these participants withdrew from the study because of an adverse reaction of hives, nausea, and vomiting to the consumption of the Reclaim supplements during week 1. After the first week, 2 participants withdrew because they were unable to pick up their prepared meals because of personal circumstances that arose after enrolling in the study. During the second week, 1 participant withdrew from the study because of being "too hungry" to continue on the low-calorie diet. After week 2, two participants withdrew from the study because they were not being compliant with the 21-day intervention program. Forty-three participants successfully completed the study protocol. Dependent variables were analyzed using the intention-to-treat approach, which assumed the same pre-post values for the 6 participants who withdrew from the study. The total number of participants included in the paired *t* test analyses was 49 (36 women, 13 men; 31 ± 10.3 years of age) based upon intention-to-treat approach and the removal of the 1 participant with the undiagnosed underlying medical condition at enrollment.

Table 1 Compliance with dietary menu—additional food consumed (percentage of person days)

Types of food	Week 1 (n = 48)	Week 2 (n = 45)	Week 3 (n = 43)
Apples	40	43	44
Almonds	42	50	45
Protein	6	11	22
Fruits/vegetables	2	6	11
Carbohydrates	6	10	12
Refined sugar	4	5	5
Tap water	0	1	1
Coffee/caffeine	8	6	7
Alcohol	2	0	1
Dairy	1	0	1

Protein included eating other nuts besides almonds or animal protein sources excluding dairy. Carbohydrates included bread, potatoes, or pasta. Refined sugar included any type of dessert. Dairy included fluid milk, cheese, or yogurt.

Allocated treatment

Tables 1 and 2 summarize compliance to the dietary menu and the 21-day intervention program. Data are expressed as a percentage of person days for each week. Person days for each week were the number participants participating multiplied by 7 days. From the weekly diaries of all participants, each occurrence of noncompliance was categorized as shown in Tables 1 and 2; and then the total of noncompliance occurrences was expressed as the percentage of person days. Throughout the 21-day intervention program, participants consumed the allowed snack option of apples and/or almonds at frequencies between 40% and 50%. The addition of protein sources to the dietary menu increased throughout the 21-day intervention program from 6% to 22%. The consumption of additional fruits, vegetables, and other carbohydrate sources also increased from 2% to 6% during week 1 to 11% to 12% during week 3. The frequencies of consumption of coffee and caffeine and refined sugars were maintained throughout the study at 6% to 8% and 4% to 5%, respectively. The participants refrained from alcohol consumption throughout the 21-day intervention program, as the frequency of consumption was only 1% to 2%.

Table 2 Compliance with 21-day intervention program (percentage of person days)

Category	Week 1 (n = 48)	Week 2 (n = 45)	Week 3 (n = 43)
Consumed all meals and supplements	58	70	60
Did not consume all the breakfast with provided supplements	7	7	5
Did not consume all the lunch with provided supplements	14	9	15
Did not consume all the dinner with provided supplements	20	12	17
Did not consume the alkalinizer between lunch and dinner	1	2	3

Table 3 Blood pressure (mean values ± SD, mm Hg)

	Preintervention	Postintervention	Difference
Right arm			
Systolic	116 ± 9.4	112 ± 8.8	−4 ± 6.7 *
Diastolic	76 ± 9.9	71 ± 8.0	−5 ± 8.4 *
Left arm			
Systolic	116 ± 9.4	112 ± 7.9	−4 ± 6.3 *
Diastolic	76 ±10.1	72 ± 7.8	−4 ± 7.8 *

* Significant at $P < .05$.

Adherence to the 21-day intervention program, both dietary menu and regimented supplementation program, occurred at an average weekly frequency of 63%. Noncompliance with the 21-day intervention program at breakfast, lunch, and dinner occurred at average weekly frequencies of 6%, 13%, and 16%, respectively. The participants consumed the alkalinizer supplement 2 hours after lunch, as the noncompliance frequency was only 1% to 3%.

Outcome measures

The 21-day intervention program decreased blood pressure from 116/76 to 112/72 mm Hg (Table 3, $P < .05$). There were pre-post intervention decreases in weight (−8.7 ± 5.54 lb; −3.9 ± 2.5 kg), BMI (− 1.4 ± 0.81 kg/m^2), waist circumference (−1.5 ± 1.14 in), hip circumference (−1.2 ± 1.24 in), waist-to-hip ratio (−0.01 ± 0.033), and waist-to-height ratio (−0.02 ± 0.018) (Table 4, $P < .05$). Pre-post intervention decreases in levels of total cholesterol (−30.0 ± 29.77 mg/dL), LDL cholesterol (−21.0 ± 25.20 mg/dL), HDL cholesterol (−6.9 ± 9.43 mg/dL), and triglycerides (−10.1 ± 34.66 mg/dL) occurred (Table 5, $P < .05$). There was a pre-post intervention increase in testosterone for men (111.0 ± 121.13 ng/dL) without a concomitant change for women (Table 6, $F_{1,47\ \text{sex} \times \text{time}} = 28.48$, $P < .05$). Pre-post intervention decreases occurred for fat mass (−5.2 ± 4.12 lb; −2.4 ± 1.9 kg) and fat-free mass (−4.0 ± 4.16 lb; −1.8 ± 1.9 kg) with an increase in percentage of fat-free mass (+1.5% ± 1.88%) (Table 7, $P < .05$). Other estimates of body composition from the BIA did not change pre-post intervention (Table 7, $P > .05$).

Table 4 Anthropometric measurements (mean values ± SD)

	Preintervention	Postintervention	Difference
Weight (lb)	175.4 ± 38.31	166.7 ± 36.69	−8.7 ± 5.54 * (7.16-10.34)
Waist (in)	36.4 ± 5.74	34.9± 5.81	−1.5 ± 1.14 * (1.13-1.78)
Hip (in)	42.0 ± 3.93	40.8 ± 3.71	−1.2 ± 1.24 * (.80-1.51)
Waist-hip ratio	0.86 ± 0.081	0.85 ± 0.087	−0.01 ± 0.033 * (.002-.021)
Height (in)	66.23 ± 2.946	66.25 ± 2.936	N/A
Waist-height ratio	0.55 ± 0.087	0.53 ± 0.088	−0.02 ± 0.018 * (0.017-0.027)
BMI (kg/m^2)	28.0 ± 5.29	26.6 ± 5.09	−1.4 ± 0.81 * (1.2-1.6)

* Significant at $P < .05$; 95th confidence intervals of the difference in parentheses.

Adverse effects

Table 8 summarizes the frequency of adverse effects. The most common adverse effect was headache, which occurred at a frequency of 22% during week 1. Headaches subsided during weeks 2 and 3 and occurred at frequencies of 8% and 3%, respectively. The headaches appeared to be due to withdrawal from caffeine during week 1. During week 3, participants did report an increase in fatigue, which occurred at a frequency of 12%. The increase in fatigue was attributed to being on a low-calorie diet for 3 weeks. From week 1 to week 3, frequency of participants reporting no adverse effects increased from 55% to 66% to 72%.

Discussion

The observational study indicated that a low–calorie-density dietary intervention plus regimented supplementation program with patient education improved weight status and lipid profiles. As discussed below, clinically meaningful differences occurred for weight loss, total cholesterol, and LDL cholesterol following the 21-day intervention program. Improvements in weight status, total cholesterol, and LDL cholesterol decrease the risk of metabolic syndrome and associated disease states, including, but not limited to, cardiovascular disease, stroke, and type II diabetes.[41] For men, a clinically meaningful improvement in testosterone levels was observed pre-post intervention. Adverse effects were tolerable, and adherence to the 21-day intervention was acceptable.

The participants experienced a weight loss of 8.7 lb (3.9 kg), on average, over a 21-day period, which was slightly less than the rapid weight loss recommendations of approximately 2% to 3% of initial body weight per week for overweight and obese adults under the supervision of a health care provider[50-53] and slightly greater than the weight loss guidelines of the Department of Health and Human Services of 1 to 2 lb per week.[54] Although BMI significantly decreased from 28.0 ± 5.29 to 26.6 ± 5.09 kg/m^2 after the 21-day

Table 5 Fasting hemoglobin A_{1c} levels and lipid profile data (mean values ± SD)

	Preintervention	Postintervention	Difference
Total cholesterol (mg/dL)	185.0 ± 39.58	155.0 ± 29.18	−30.0 ± 29.77 * (21.4-38.5)
HDL (mg/dL)	63.7 ± 15.77	56.8 ± 13.71	−6.9 ± 9.43 * (4.3-9.7)
LDL (mg/dL)	102.7 ± 36.92	81.7 ± 24.40	−21.0 ± 25.20 * (13.7-28.2)
Triglycerides (mg/dL)	93.1 ± 47.41	83.0 ± 30.86	−10.1 ± 34.66 * (0.1-20.0)

* Significant at $P < .05$; 95th confidence intervals of the difference in parentheses.

Table 6 Testosterone (in nanograms per deciliter) by sex (mean values ± SD)

	Preintervention	Postintervention	Difference
Women	32.5 ± 12.82	32.5 ± 22.97	0.0 ± 22.91 (−7.7 to +7.8)
Men	400.8 ± 125.06	511.8 ± 188.06	+111.0 ± 121.13 * (37.8-184.2)

* Significant at $P < .05$; 95th confidence intervals of the difference in parentheses.

intervention program, the participants remained in the overweight category pre-post intervention. Waist-to-hip ratio and waist-to-height ratio are other indices of improvements in weight status and discriminators of cardiovascular risk factors. The recommended waist-to-hip ratios, which are associated with a decreased risk for cardiovascular disease, are less than 0.83 for women and less than 0.90 for men.[55] Pre-post changes in the waist-to-hip ratios were not clinically meaningful, as both the men (0.92 to 0.91) and women (0.84 to 0.83) remained in the at-risk category throughout the study period. Similarly, the decrease in the waist-to-height ratio from 0.55 to 0.53 was not deemed clinically meaningful because waist-to-height ratios less than 0.50 are associated with a decreased risk for cardiovascular disease.[56,57]

Normative values from the National Cholesterol Education Program were used to define clinically meaningful differences in cholesterol levels.[58,59] Although total cholesterol levels were less than the National Cholesterol Education Program target level of 200 mg/dL at preintervention (185 mg/dL), the pre-post intervention decrease of 30 mg/dL was still deemed clinically meaningful, as a total cholesterol level of 155 mg/dL after the 21-day intervention program reflects a more favorable lipid profile. The preintervention LDL cholesterol levels of 103 mg/dL decreased by 21 to 83 mg/dL after the 21-day intervention program. This pre-post intervention decrease is clinically meaningful within the context of LDL cholesterol levels being less than 100 mg/dL as ideal for reducing the risk of cardiovascular disease and the most recent recommendation to change the ideal target to less than 70 mg/dL.[59] Despite the significant decreases in triglycerides and HDL cholesterol levels pre-post intervention, both lipid profile indices were at optimal or near-optimal levels throughout study period, less than 100 mg/dL for triglycerides and less than 60 mg/dL for HDL cholesterol. In addition, a decrease in HDL cholesterol is expected when participants are participating in a calorie-restricted, low–calorie-density dietary intervention.[60,61]

In agreement with previous literature on low–calorie-density diets and portion size restriction,[2,3] improvements in total cholesterol and LDL cholesterol levels occurred concomitantly with weight loss after the 21-day intervention program. The low attrition rate of 14% with adequate adherence to the 21-day intervention program was most likely due to the ease of consuming quality, portion-controlled meals and nutritional supplements with the support of coaching and the short duration of the intervention.[62-65] However, the

Table 7 Estimates of body composition (mean values ± SD)

	Preintervention	Postintervention	Difference
Total body water (L)	40.3 ± 8.91	38.9 ± 8.18	−1.4 ± 1.74 * (.9-1.9)
Intracellular water (%)	55.2 ± 4.10	55.6 ± 4.57	+0.4 ± 2.25 (−1.0 to +0.3)
Extracellular water (%)	44.8 ± 4.10	44.8 ± 4.71	0.0 ± 2.84 (−0.8 to + 0.8)
Fat mass (lb)	52.4 ± 21.02	47.2 ± 20.36	−5.2 ± 4.12 * (4.0-6.4)
Fat mass (%)	29.3 ± 7.11	28.3 ± 8.96	−1.0 ± 4.39 (−0.3 to +2.2)
Fat-free mass (lb)	123.2 ± 25.11	119.2 ± 23.77	−4.0 ± 4.16 * (2.9-5.2)
Fat-free mass (%)	70.7 ± 7.11	72.2 ± 7.45	+1.5 ± 1.88 * (1.0-2.0)

* Significant at $P < .05$; 95th confidence intervals of the difference in parentheses.

Table 8 Adverse effects (percentage of person days)

Adverse effects	Week 1 (n = 48)	Week 2 (n = 45)	Week 3 (n = 43)
Headache	22	8	3
Dizziness	1	2	2
Fatigue	6	4	12
Constipation	1	5	3
Hunger	2	2	2
Nausea	4	5	0
Loose stool	3	1	2
Cold/chilled	1	1	0
Gassy/cramps	1	3	0
Allergic-type reaction	1	2	1
Enlarged lymph nodes	1	1	0
Muscle cramps	1	0	3
Loss of appetite	1	0	0
No symptoms	55	66	72

progressive increase in the consumption of foods high in protein, which was in addition to meals provided and included eating other nuts besides almonds or animal protein sources excluding dairy, suggests that a low–calorie-density dietary intervention needs to maintain adequate levels of dietary protein for many individuals. In support of this suggestion,[66] the 21-day intervention program induced a decrease in fat-free mass of 4 lb (1.8 kg), 3 lb (1.4 kg) due to water loss and 1 lb (0.4 kg) due to muscle loss, as well as inducing a 5-lb (2.3 kg) decrease in fat mass. Increasing protein intake during the 21-day intervention program may be necessary to prevent the loss of muscle mass, as the literature suggests that high-protein weight loss diets reduce fat mass while maintaining lean body mass.[66-70] Intracellular and extracellular water percentages were within normal limits pre-post intervention.[45]

Among men, there is an inverse relationship between weight status indices, BMI, and waist circumference, and serum testosterone levels ($r = -.45$).[71-73] Furthermore, serum testosterone levels between 450 and 600 ng/dL are associated with decreased risk for cardiovascular disease, type II diabetes mellitus, and metabolic syndrome.[cf73] Although more conclusive evidence is needed,[73] increases in serum testosterone levels of 11% to 24% have been shown to accompany weight loss from restricted calorie diets in obese men.[74,75] In the current study, the 28% increase in serum testosterone levels from 400.8 to 511.8 ng/dL for men was consistent with previous reports on weight loss with a restricted-calorie diet and reflected a clinically meaningful difference with respect to reducing the risk for chronic diseases. Despite having only 13 men in the study, the correlation between pre-post invention changes in serum testosterone levels and BMI was $r = -.44$. Among our female participants, serum testosterone levels were within the reference range, 8 to 60 ng/dL, at preintervention and did not change after the 21-day intervention program.

Limitations

As an observational study, the lack of blinding, randomization, and a control group limits the generalizability of the results. Participant selection bias limits the generalizability of the results. Participants only logged compliance with the consumption of prepared meals plus regimented supplementation program, and the return of the supplement products was not required. Thus, our adherence data may be inflated. The multicomponent nature of dietary intervention plus regimented supplementation program with coaching and no control group precludes us from making specific recommendations on the use of nutritional supplements such as (1) probiotic and prebiotic nutritional supplementation and colon-cleansing products as critical elements for initiating and maintaining weight loss or (2) nutritional supplements containing enzymes to facilitate digestion, reduce cholesterol levels, increase metabolic rate, and mediate inflammatory processes. However, according to current empirical recommendations, the colon-cleanse product was used during the initial stages of a weight loss program; and the nutritional supplements, for example, enzymes, prebiotics and probiotics, were used daily. Future studies need to address the potential additive effects of supplementation programs, that is, independent of dietary interventions alone, on weight loss, weight maintenance, and lipid profiles.

Conclusion

Weight loss and improvements in total cholesterol and LDL cholesterol levels occurred after a low–calorie-density dietary intervention plus regimented supplementation program.

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