Original Research

Pistachio Nuts Reduce Triglycerides and Body Weight by Comparison to Refined Carbohydrate Snack in Obese Subjects on a 12-Week Weight Loss Program

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Objective: There is a widely held view that, due to high fat content, snacking on nuts will lead to weight gain, ultimately causing unhealthy changes in lipid profiles. This study is designed to study the effects of pistachio snack consumption on body weight and lipid levels in obese participants under real-world conditions.

Methods: Participants were randomly assigned to consume 1 of 2 isocaloric weight reduction diets for 12 weeks, with each providing 500 cal per day less than resting metabolic rate. Each diet included an afternoon snack of either 53 g (240 cal) of salted pistachios (n = 31) or 56 g of salted pretzels (220 cal; n = 28).

Results: Both groups lost weight during the 12-week study (time trend, $p < 0.001$), but there were significant differences in the changes in body mass index between the pretzel and pistachio groups (pistachio, 30.1 ± 0.4 to 28.8 ± 0.4 vs. pretzel, 30.9 ± 0.4 to 30.3 ± 0.5). At 6 and 12 weeks, triglycerides were significantly lower in the pistachio group compared with the pretzel group (88.04 ± 9.80 mg/dL vs. 144.56 ± 18.86 mg/dL, $p = 0.01$ at 6 weeks and 88.10 ± 6.78 mg/dL vs. 132.15 ± 16.76 mg/dL, $p = 0.02$ at 12 weeks), and there was a time trend difference between the 2 groups over the 12 weeks ($p < 0.01$). There were no significant differences in total cholesterol, high-density lipoprotein cholesterol, low-density lipoprotein cholesterol, insulin, or glucose between the 2 groups.

Conclusion: Pistachios can be consumed as a portion-controlled snack for individuals restricting calories to lose weight without concern that pistachios will cause weight gain. By comparison to refined carbohydrate snacks such as pretzels, pistachios may have beneficial effects on triglycerides as well.

INTRODUCTION

There is a widely held view that increased consumption of a fatty food, such as nuts, may lead to weight gain in the population at large. Conversely, a number of publications have described associations between the frequent consumption of small quantities of nuts, foods rich in unsaturated fats, and lower rates of coronary heart disease events [1–5]. Several large epidemiologic studies that recorded data on nut consumption consistently suggest such an effect [5–8].

Although fat has a poor reputation for being more likely to cause weight gain than other sources of calories [9–12], evidence from epidemiological studies suggest that nut consumption is not associated with increased body weight [3,13,14]. Clinical trials have consistently demonstrated that the inclusion of nuts in the diet leads to little or no weight gain [15,16]. A randomized crossover experiment by Fraser and coworkers [15] found that consuming approximately 2 oz (320 cal) of almonds each day over a period of 6 months did not change body weight significantly. In a weight management program, Wien et al. [17] compared almonds to complex carbohydrates in 65 individuals and found the almond group had more favorable reductions in body weight and body mass index (BMI).

The present study examined the hypothesis that consumption of 53 g of pistachio nuts (about 75 kernels = 240 cal) per day as part of a weight reduction diet by comparison to an isocaloric diet with pretzels will not interfere with the attempt for weight loss and will improve lipid profile.

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MATERIAL AND METHODS

Participants

The study protocol was approved by the University of California, Los Angeles, Institutional Review Board. Participants were recruited by public advertisements, and all gave written consent. Individuals between the ages of 20 and 65 years with a BMI between 27 to 35 kg/m^2 and in good health by history, physical examination, and basic laboratory screening (complete blood count, serum chemistry, liver function, and lipid panel) were selected for the study. Participants with type 2 diabetes or glucose intolerance, hypercholesterolemia, and currently taking cholesterol-lowering agents were excluded, as were individuals who regularly drank more than 1 alcoholic beverage daily. Participants who met the selection criteria were randomly assigned to either the pistachio or pretzel group in a 1:1 manner using a computerized random proportion model.

Dietary Intervention

Free-living participants were given meal plans at the beginning of the study by the dietitian providing 500 cal per day less than resting metabolic rate estimated based on lean body mass measured by bioimpedance analysis (Biodynamics Inc., Seattle, WA). A meal plan for either 1200, 1400, or 1600 cal was provided based on the calories to be provided according to the above parameters. A daily snack of 53 g pistachio or 56 g of pretzel was included in the individual meal plans. Pistachios were provided in packages of 53 g salted edible pistachios (84 g with shell; Sunkist California Pistachios, Paramount Farms, Inc., Los Angeles, CA). Pretzels were provided in a package (Rold Gold Pretzels Classic Style Tiny Twists, Frito-Lay, Inc., Plano, TX). Meals were isocaloric but had different macronutrient compositions with pistachios replaced carbohydrates for the pistachio group. The pretzel meal plan was approximately 20% fat diet, 15% protein, and 65% carbohydrate, and the pistachio group meal plan was 30% fat, 15% protein, and 55% carbohydrate.

Participants prepared their own food and were asked to record their daily food intake on a weekly food record. Daily food intake was recorded using a checklist including study snack and servings of macronutrients from the meal plan. At baseline and at weeks 2, 4, 6, 8, 10, and 12, participants met with the research dietitian to ensure compliance with the diet.

Body Weight

Participants were weighed, barefoot and after an overnight fast, at each visit (weeks −2, 0, 2, 4, 6, 8, 10, 12; Detecto-Medic, Deteco-Scales, Brooklyn, NY). Height was measured with a stadiometer (Detecto-Medic, Deteco-Scales) at week 0. BMI was calculated as weight (kg)/height squared (m).

Biochemistry

Fasting blood samples were collected at week 0, 6, and 12 for measurement of serum lipid profiles, insulin, glucose, and electrolyte concentrations.

Serum cholesterol, high-density lipoprotein (HDL) cholesterol, and triglyceride concentrations were determined using standard enzymatic methods. Reagents, standards, and calibrators were purchased from Pointe Scientific (Lincoln Park, MI). HDL or alpha cholesterol was derived from the cholesterol measurement of the supernatant following the precipitation of apo B containing lipoproteins with heparin and $MnCl_2$. Low-density lipoprotein (LDL) or beta lipoprotein cholesterol was estimated from these data using the Friedewald equation. The interassay coefficients of variation (CVs) were less than 4%, and the intra-assay variation was less than 2%. Insulin was determined using the Siemens Immulite immunoassay system (Deerfield, IL). The assay is a solid-phase, 2-site chemiluminescent immunometric assays using beads coated with monoclonal murine anti-insulin. The interassay CVs for insulin were 5.9% (25.5 μIU/mL) and 7.0% (300 μIU/mL).

Data Management and Statistical Analyses

The primary outcome variables were the changes in weight and BMI over 12 weeks. Statistical analyses were performed using SAS software 9.2 (SAS Institute Inc., Cary, NC). Data were expressed as least squares mean ± standard errors and checked for normality. A paired *t* test or Wilcoxon sign rank test was used to evaluate the change of outcomes from baseline to 12 weeks. A 2-sample *t* test or Wilcoxon rank sum test was used to compare the change of outcomes at 12 weeks between diets. Repeated measurement analysis was carried out using the linear mixed-effects model to examine the time trends of the outcomes. P values <0.05 were considered statistically significant.

RESULTS

Participants

Of the 95 potential participants who were screened, 70 of them met both the inclusion and exclusion criteria and were enrolled into the study. Thirty-six subjects were randomized to the pistachio group and 34 to the pretzel group. At the time of randomization, 5 participants from the pistachio group and 6 from the pretzel group withdrew from the study due to their dissatisfaction with their group assignments. As a result, 31 and 28 participants entered the study for the pistachio and pretzel groups, respectively. Three participants from each group were found to be noncompliant with the daily food log or study visit or were lost to follow-up and consequently were dropped from the study. One participant in the pistachio group

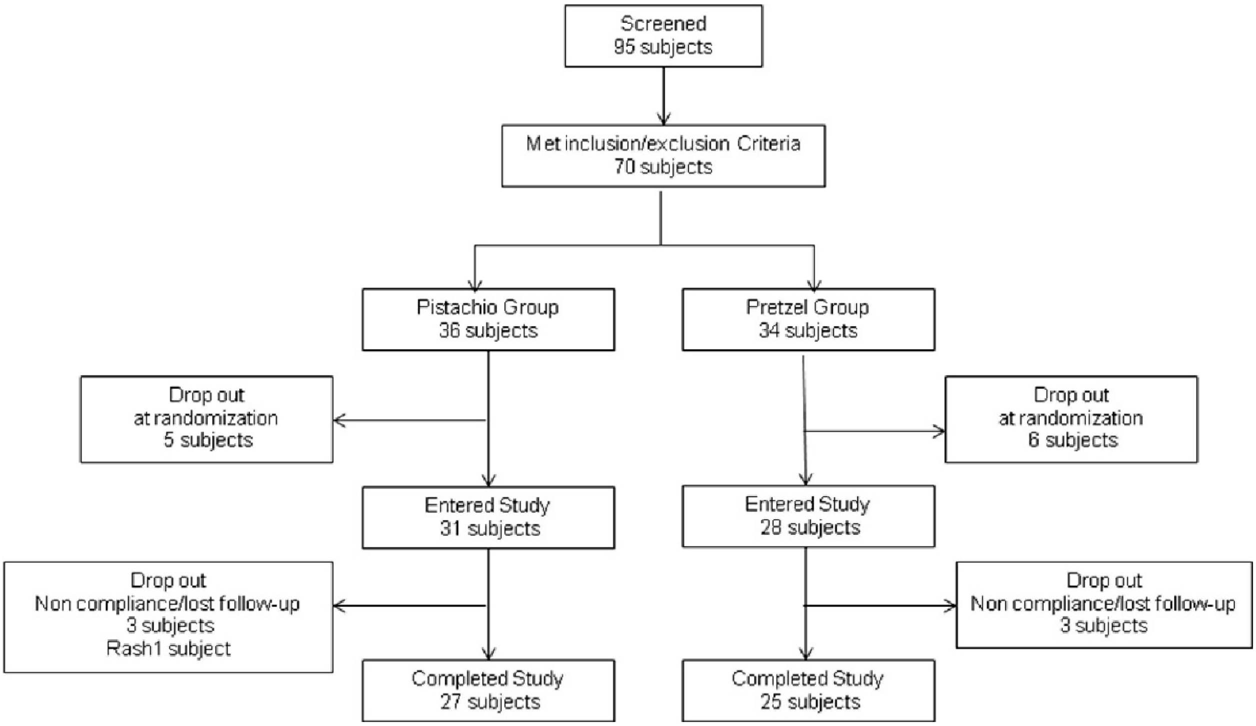

Fig. 1. Study participant enrollment flow chart.

with no previous allergy to pistachio experienced a rash and was discontinued from the study. In total, 52 participants (27 in the pistachio group and 25 in the pretzel group) finished the 12-week study (Fig. 1). Both groups were well matched with similar baseline characteristics (Table 1). There were no significant adverse events.

Body Weight

There was no significant difference of body weight at baseline between the 2 groups. Both groups lost weight beginning at the second week of the study (time trend, $p < 0.001$ linear mixed-effects model). At the end of the study, both groups lost significant amounts of weight from baseline (pistachio group from 86.0 ± 1.4 to 82.3 ± 1.6 kg, $p < 0.01$; pretzel group from 85.5 ± 2.2 to 82.8 ± 2.5 kg, $p < 0.01$ with paired *t* test). While there was a trend for the pistachio group to lose more weight than the pretzel group, the differences were not statistically significant ($p = 0.09$ linear mixed-effects model).

At 12 weeks, the BMI of the pistachio group decreased from 30.1 ± 0.4 at baseline to 28.8 ± 0.4 kg/m^2 ($p < 0.05$ with paired *t* test), while the pretzel group changed from 30.9 ± 0.4 to 30.3 ± 0.5 kg/m^2 ($p < 0.05$ with paired *t* test). There was a significantly greater reduction in BMI in the pistachio group (4.3% of BMI) than in the pretzel group (2% of BMI) through the 12 weeks of the study, except during week 10, when the *p* value of the difference between groups was 0.08 (Fig. 2).

Lipids, Glucose, and Insulin

The total cholesterol levels at the beginning of the study were 197.4 ± 5.6 mg/dL for the pistachio group and 204.5 ± 8.4 mg/dL for the pretzel group. Although total cholesterol levels decreased slightly in both groups, neither decrease was statistically significant. On the other hand, fasting triglyceride levels were within reference range at week 0 (pistachio 113.0 ± 14.2 mg/dL vs. pretzel 134.2 ± 14.4, $p = 0.302$, 2-sample *t* test). For the pistachio group, triglyceride levels decreased significantly at weeks 6 and 12 compared with the pretzel group (88.04 ± 9.80 mg/dL vs. 144.56 ± 18.86 mg/dL, $p = 0.01$ at 6 weeks and 88.10 ± 6.78 mg/dL vs. 132.15 ± 16.76 mg/dL, $p = 0.02$ at 12 weeks, 2-sample *t* test). Repeated measurement analysis looking at time trend, with baseline as covariate, was performed. The *p* value was 0.023. No significant change was observed for LDL and HDL in either group during the interventions; however, the HDL level was well preserved in both groups (Table 2).

The fasting serum glucose concentration did not change significantly for either group. The insulin was consistently decreased by 18.5% at 6 weeks and 23.7% at 12 weeks for the pistachio group, but the differences between the 2 groups was not statistically significant. The pretzel group was noted to have a higher insulin level at week 12 compared with the pistachio group ($p = 0.072$, sample *t* test), but the difference was not statistically significant (Table 2).

Table 1. Baseline Characteristics

Characteristic	Pistachio	Pretzel
Women, no. (%)	28 (75.7)	29 (85.2)
Age (yr), mean (SE)	45.4 (2.0)	47.3 (2.3)
Race, no. (%)		
Asian	1 (2.7)	2 (5.9)
Black	8 (21.6)	6 (17.6)
Caucasian	18 (48.6)	15 (44.1)
Hispanic	7 (18.9)	6 (17.6)
Other	3 (8.1)	5 (14.7)
Weight, kg (SE)	86.0 (3.2)	85.5 (4.8)
Body mass index, kg/m^2 (SE)	30.1 (0.4)	30.9 (0.4)

DISCUSSION

The consumption of pistachios and other nuts is associated with reduced risks of heart disease when eaten as part of a healthy low-fat diet [1–3]. Compared with other commonly consumed nuts, pistachios have a unique nutrient profile. They are a good source of unsaturated fatty acids and numerous antioxidants, including γ-tocopherol, β-carotene, lutein, selenium, flavonoids, and phytoestrogens [18,19]. Our group recently described the unique content of anthocyanins in the peel and lutein in the pistachio nut [20]. On the other hand, the high energy density of pistachios and other nuts has raised concerns that their consumption could lead to weight gain, undoing any benefit of pistachio consumption on cardiovascular risk.

The present study is the first to investigate pistachio nut consumption as part of a weight loss management plan. We observed more weight loss with consumption of 53 g of pistachios per day compared with an isocaloric refined carbohydrate snack consisting of pretzels.

There are several possible explanations for the greater weight loss observed following the consumption of pistachios compared with pretzels. Nuts provide greater satiety, which could explain the reduced hunger participants reported on questionnaires [21]. Cassady et al. [22] reported that mastication can potentiate the satiety effects of almonds likely by elevating postprandial glucagon-like peptide-1 and decreasing insulin levels. Nuts contain fiber, protein, unsaturated fats, and various phytochemicals; require substantial oral processing before swallowing; have distinct flavor profiles; and are widely believed to be energy rich, all of which have been associated with satiety responses [23].

The fat in the pistachio may not be fully bioavailable. Ellis et al. [24] investigated the role played by cell walls in influencing the bioavailabilty of the intracellular lipid in almond seeds. They found that the cell walls of almond reduced the bioavailability of cellular lipids. Cell walls that are not ruptured during mastication may pass through the gastrointestinal tract without releasing the oil they contain and would possibly limit the bioavailability of other nutrients they contain [25].

It is also possible that chronic consumption of nuts increased energy expenditure. One small study of almond intake demonstrated a 209-kJ (49.8-cal) per day increase in resting energy expenditure, and this finding was corroborated by doubly labeled water measurement [16].

However, there are insufficient data to definitively support any of the above mechanisms for dissipation of the energy provided by nuts. Mattes and Dreher [23] estimated that 55% to 75% of the energy contributed by nuts is offset by dietary compensation, another 10% to 15% by fecal loss, and an additional, less well-established, estimate of 10% via increased energy expenditure [23].

Several studies have examined the effects of high monounsaturated fatty acid diets on plasma lipids, primarily by enriching the diets with nuts or olive oil. Rajaram et al. [1] conducted a randomized, controlled crossover feeding study to

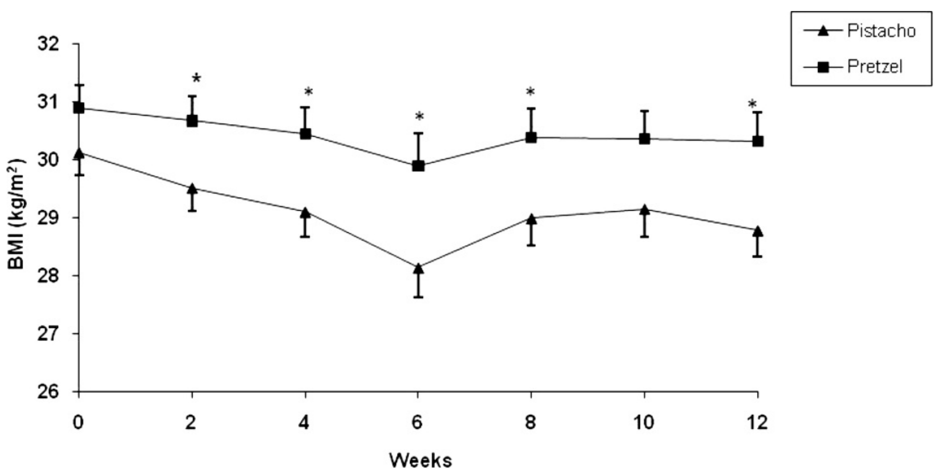

Fig. 2. Change of body mass index in 12 weeks with pistachio and pretzel snacks.

Table 2. Change of Lipid, Glucose, and Insulin

	Pistachio			Pretzel		
Week	0	6	12	0	6	12
Cholesterol (mg/dL)	197.4 ± 5.6	191.4 ± 7.3	191.6 ± 7.5	204.5 ± 8.4	191.1 ± 7.5	183.2 ± 8.2
Tryglyceride (mg/dL)	113.0 ± 14.2	88.0 ± 9.8*	88.1 ± 6.8*	134.2 ± 14.4	144.6 ± 18.9	132.1 ± 16.8
Low-density lipoprotein (mg/dL)	83.1 ± 10.6	83.4 ± 11.8	79.9 ± 11.0	80.5 ± 12.2	76.8 ± 10.8	72.9 ± 10.7
High-density lipoprotein (mg/dL)	43.8 ± 2.0	40.3 ± 2.6	42.9 ± 2.5	40.1 ± 2.6	38.7 ± 2.6	39.5 ± 2.5
Glucose (mg/dL)	87.7 ± 2.9	86.8 ± 2.6	83.7 ± 2.4	96.8 ± 8.5	87.1 ± 2.2	88.9 ± 2.3
Insulin (μIU/ml)	11.4 ± 1.8	9.3 ± 1.4	8.7 ± 1.0	14.8 ± 3.0	11.5 ± 1.2	16.2 ± 3.9

* $p < 0.05$ between the groups.

compare an American Heart Association (AHA) Step I diet with 28.3% energy from fat to a pecan-supplemented diet with a 20% isoenergetic replacement with pecans, resulting in 39.6% energy from fat. The pecan-supplemented diet decreased serum total cholesterol, LDL cholesterol, and HDL cholesterol beyond that observed with the Step I diet, with no increases in body weight. Curb et al. [26] examined changes in serum lipid levels in response to a macadamia nut–supplemented diet. Thirty individuals participated in a randomized crossover trial of three 30-day diets of either (1) a typical Western diet high in saturated fat with 37% of energy from fat, (2) an AHA Step I diet, or (3) a macadamia nut–based diet with 37% of energy from fat. Both experimental diets reduced total cholesterol and LDL cholesterol, and the macadamia nut diet resulted in lower triglyceride values than the Step 1 diet did. Similar observations have been made for diets enriched in peanuts/peanut oil [27], almond [28], and olive oil [29].

Obese participants enrolled in the current study had normal cholesterol and triglyceride levels, and yet daily pistachio consumption resulted in a significant further reduction of triglycerides, a trend toward reduction for total cholesterol, with no change of HDL or LDL. Previous studies have demonstrated significant improvement of lipid profiles in individuals with hypercholesterolemia [2,30] and healthy volunteers [31] but no significant change of LDL or triglycerides. Rajaram et al. [32] analyzed the effect of a fish-rich diet on total cholesterol in separate groups of participants with low, moderate, and high baseline cholesterol and reported a significant progressively greater decrease of cholesterol in the moderate and high baseline groups. In all of the above studies, participants were to consume pistachios under free-living conditions. Gebauer et al. [4] conducted a controlled-feeding study and was first to report significant reductions in LDL cholesterol after consumption of pistachios. In the context of a heart-healthy diet, adding as little as 32 to 63 g of pistachios per day lowered LDL cholesterol by 9%. The present study was conducted in individuals with normal cholesterol levels who consumed pistachios as an outpatient, which may explain the differences from other studies reviewed above.

CONCLUSION

Pistachios are a healthy snack that can be included in a weight management program without fear that they will cause weight gain in free-living individuals. The pistachio snacks were provided in portion-controlled packets, and we are not implying that uncontrolled intake would provide the same result. Consumers should count out pistachios equivalent to 2 oz if portion-controlled packets are not available. Pistachio snacks result in lower triglyceride levels consistent with the known benefits of monounsaturated fats versus refined carbohydrates on lipids.

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Statement of Authors' Contributions to the Manuscript

Z. Li and D. Heber designed research and wrote the paper; R. Song, C. Nguyen, A. Zerlin, H. Karp, K. Naowamondhol, G. Thames, K. Gao, L. Li, S.M. Henning conducted research. C.-H. Tseng performed statistic analysis. All authors read and approved the final manuscript.

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