Original Research

Pistachio Nut Consumption and Serum Lipid Levels

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Objective: Clinical and epidemiological studies have reported the beneficial effects of tree nuts and peanuts on serum lipid levels. We studied the effects of consuming 15% of the daily caloric intake in the form of pistachio nuts on the lipid profiles of free-living human subjects with primary, moderate hypercholesterolemia (serum cholesterol greater than 210 mg/dL).

Methods: Design: Randomized crossover trial. Setting: Outpatient dietary counseling and blood analysis. Subjects: 15 subjects with moderate hypercholesterolemia. Intervention: Fours weeks of dietary modification with 15% caloric intake from pistachio nuts. Measures of Outcome: Endpoints were serum lipid levels of total cholesterol, HDL-C, LDL-C, VLDL-C, triglycerides and apolipoproteins A-1 and B-100. BMI, blood pressure, and nutrient intake (total energy, fat, protein, and fiber) were also measured at baseline, during, and after dietary intervention.

Results: No statistically significant differences were observed for total energy or percent of energy from protein, carbohydrate or fat. On the pistachio nut diet, a statistically significant decrease was seen for percent energy from saturated fat (mean difference, −2.7%; 95% CI, −5.4% to −0.08%; $p = 0.04$). On the pistachio nut diet, statistically significant increases were seen for percent energy from polyunsaturated fat (mean difference, 6.5%; 95% CI, 4.2% to 8.9%; $p<.0001$) and fiber intake (mean difference, 15g; 95% CI, 8.4g to 22g; $p = 0.0003$). On the pistachio diet, statistically significant reductions were seen in TC/HDL-C (mean difference, −0.38; 95% CI, −0.57 to −0.19; $p = 0.001$), LDL-C/HDL-C (mean difference, −0.40; 95% CI, −0.66 to −0.15; $p = 0.004$), B-100/A-1 (mean difference, −0.11; 95% CI, −0.19 to −0.03; $p = 0.009$) and a statistically significant increase was seen in HDL-C (mean difference, 2.3; 95% CI, 0.48 to 4.0; $p = 0.02$). No statistically significant differences were seen for total cholesterol, triglycerides, LDL-C, VLDL-C, apolipoprotein A-1 or apolipoprotein B-100. No changes were observed in BMI or blood pressure.

Conclusion: A diet consisting of 15% of calories as pistachio nuts (about 2–3 ounces per day) over a four week period can favorably improve some lipid profiles in subjects with moderate hypercholesterolemia and may reduce risk of coronary disease.

INTRODUCTION

Coronary heart disease (CHD) remains the leading cause of death accounting for 29.5% of all deaths in the United States and hypercholesterolemia, which affects nearly 100 million adults, is a significant risk factor. Early population studies strongly suggested a relationship between total and saturated fat intake and CHD [1,2] and for many years reduction in total fat intake, saturated fat and cholesterol was the primary dietary recommendation to lower serum cholesterol. However, recently revised national dietary recommendations for major health organizations have de-emphasized the role of lowering total fat in the prevention of coronary heart disease [3–6]. Mounting evidence from metabolic [7–10], observational [11–13] and epidemiological studies [14–25] has shown that diets high in unsaturated fats can reduce cholesterol levels and suggest that lowering saturated fat and replacing carbohydrates with unsaturated fats is more effective in preventing CHD than reducing overall fat intake. The American Heart Association recommends that up to 20% of calories come from monounsaturated fat [3]. Dietary approaches focusing exclusively on the reduction of saturated fat and cholesterol may also reduce HDL-C levels, adversely affecting TC/HDL-C and LDL-C/HDL-C ratios [26,27].

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Until recently, nuts have not been considered a food choice to include in heart healthy diets due to their fat and calorie content, but several large prospective studies all have found an inverse relationship between nut consumption and CHD risk [28–32]. At least twenty clinical studies have reported the beneficial effects of diets containing specific tree nuts and peanuts on serum lipid levels [33–53]. In comparison to the reported total cholesterol reduction of ≈3–14% in a Step 1 diet [54], these nut containing diets reduced total cholesterol by ≈4–16% and LDL-C by ≈9–20% [47]. Although all nuts contain calories and have high levels of either monounsaturated or polyunsaturated fats, and low levels of saturated fats, the fatty acid composition of each type of nut varies [54]. The benefit of nuts has been attributed to their high level of monounsaturated and polyunsaturated fats, in spite of their calorie content. Since pistachio nuts contain predominantly monounsaturated fat one would expect that consuming pistachio nuts to increase the monounsaturated fat in the diet might also be capable of improving the lipid profile without following a low fat diet. For this reason, we chose to study whether consuming pistachio nuts at 15% of calories could have a significant impact on lipid profiles of subjects with moderate hypercholesterolemia. This study is a prospective dietary intervention evaluating the effect of pistachio nuts on a small number of free-living individuals.

MATERIALS AND METHODS

Subjects

Subjects with moderate hypercholestrolemia (cholesterol >210 mg/dL) [6] were obtained by community advertisement or by physician referral and screened by a nurse clinical coordinator. Excluded were subjects being treated for hyperlipidemia, hypertension, diabetes mellitus, and kidney or liver disease. Also excluded were subjects under the age of 18, those with known food allergies, smokers, those consuming >3 alcoholic drinks per week, and women on hormone therapy. All subjects were asked not to modify their lifestyle activities, including exercise, and to record in a diary any new medications taken or symptoms of illness.

Twenty subjects met the selection criteria and were enrolled in the study. During the five-day baseline period, five male subjects withdrew. All cited time commitment and scheduling inconvenience as their primary reason. Fifteen subjects continued and finished the study, 11 men and 4 women, whose ages ranged from 36 to 75 years. At baseline, these subjects had an average (mean ± SEM) age of 60 ± 3 years, a body mass index of 28 ± 0.9 and a fasting serum cholesterol of 246 ± 6 mg/dL. Average triglyceride levels were 141 ± 11 mg/dL, systolic blood pressure 129 ± 4 mm Hg, diastolic blood pressure 84 ± 3 mm Hg and pulse 78 ± 2.

Experimental Design

A prospective, randomized, crossover design was utilized, with subjects serving as their own controls. All subjects consumed their normal diets during a five-day baseline period. Subsequently, seven subjects were randomized to the pistachio diet for four weeks followed by four weeks on the regular diet, while eight subjects followed these diets in the reverse order. All subjects had their lipid profiles measured during the second and fourth weeks of each 4-week dietary period. Study personnel performing the statistical analyses were blinded to the dietary sequence of the subject. The study was not designed to examine any carry-over effects from the pistachio diet to the regular diet.

The protocol was approved by the Inova Institutional Review Board at the Inova Fairfax Hospital and all subjects gave informed consent. Subjects were offered an honorarium of $300 for their participation, with payments of $25 for each of the first five visits and the remaining $175 paid at the conclusion of the study.

Dietary Intervention

Each subject was required to submit a consecutive three-day food diary before entering the baseline period and before any scheduled meetings with the dietitian. Food diaries were analyzed for total energy (kcal) and percent of macronutrient content (protein, carbohydrate, saturated, monounsaturated and polyunsaturated fats, and dietary fiber). Seven patients were then randomized to a pistachio diet. The intervention diet involved consuming pistachio nuts for 15% of their daily caloric intake, about 2 to 3 ounces per day. Pistachios were given out in pre-measured storage bags, whose kcal/day content was calculated for each individual subject. Subjects were instructed to substitute the pistachio nuts for normally consumed high fat snacks. Subjects who did not normally consume high-fat snacks were asked to substitute pistachio nuts as fat calories. Otherwise, the subjects consumed their normal, regular diets. For each week of the pistachio diet, subjects kept one-day food records that were analyzed to ensure that the subjects were consuming the assigned quantity of pistachio nuts. There was no definitive compliance measure of pistachio consumption. Subjects were asked to return their pistachio storage bags at each visit. All eleven of the male subjects and two of the four female subjects were accompanied by a spouse or family member, who was queried about pistachio consumption at each of the study visits. The dietitian met weekly with each subject to discuss any issues regarding pistachio consumption. After four weeks the subjects switched diets, with those on the pistachio diet crossing over to their regular diet, and vice versa. There was no lag time between diets.

Measurements

Body weight, height, and blood pressure for each subject were measured during the baseline period and during weeks 2 and 4 of each dietary phase. Bodyweight and height were measured without heavy clothing or shoes and recorded as body mass index (weight in kilograms divided by the square of the height in meters). Blood pressures were obtained after a five-minute rest in a sitting position. One-day food diaries were obtained each week and analyzed using *Nutritionist Five*™ software (First Databank, San Bruno, CA). At weekly intervals, a registered dietitian calculated the total daily caloric intake as well as its macronutrient composition to ensure that the diets did not change significantly. Subjects were asked to maintain the same physical activity and other lifestyle habits throughout the study, and to record in their diaries any signs of illness and new medications taken.

Lipid profiles for each subject also were measured during the baseline period and during weeks 2 and 4 of each dietary phase. After an overnight fast, two 10 cc of venous blood was drawn from an antecubital vein and collected in tubes containing EDTA. All blood samples were analyzed within one day at American Medical Laboratories, Inc. (Chantilly, VA). High-density lipoprotein (HDL) cholesterol was separated from the plasma and measured using the method of Warnick [55]. Total cholesterol in the remaining plasma and triglycerides were measured by an enzymatic procedure on a Hitachi 747-200 analyzer (Roche Diagnostics, Indianapolis, IN). Low-density lipoprotein (LDL) cholesterol was calculated by subtraction using the method of Friedewald [56]. Apolipoproteins A-1 and B-100 were measured by immunonephelometry on a BN-II (Behring Diagnostics, Newark, DE). All procedures were performed according to the Lipid Standardization Program of the Centers for Disease Control and Prevention, and the National Heart, Lung and Blood Institute.

Statistical Analysis

The sample size estimate was based on a difference in LDL-C of 15mg/dL between the pistachio and regular diets and a standard deviation of 20mg/dL for the distribution about both means for a power of 0.80 and a type 1 error of $\alpha = 0.05$. The required number of subjects to detect this difference was 15. As no differences in outcome trends were seen based on the sequence of the diets, outcome data were aligned and are presented as baseline values, pistachio diet values, regular diet values, irrespective of the diet sequence (i.e., pistachio -> regular, regular -> pistachio). The values of all lipid and nutritional variables used in the analysis were the average measurements at week 0 (baseline), week 4 and week 8. Results are reported as means ± SEMs and mean differences ± 95% CIs unless otherwise noted. Changes over time were evaluated using a repeated measures analysis-of-variance technique. For a comparison of each outcome, a level of $\alpha \leq 0.05$ was considered statistically significant. All analyses were conducted using SAS software (v8.2, SAS Institute, Cary, NC.).

RESULTS

Blood Pressure and Body Mass Index

There were no statistically significant changes in blood pressure or body mass index (BMI) during the study (Table 1).

Dietary Intake

No differences were seen for total energy or percent of total energy from protein, carbohydrate, total fat or monounsaturated fat intake (Table 2). On the pistachio diet, a statistically significant decrease was seen for saturated fat intake (mean difference, −2.7%; 95% CI, −5.4% to −0.10%; $p = 0.04$). Statistically significant increases favoring the pistachio diet also were observed for polyunsaturated fat intake (mean difference, 6.5%; 95% CI, 4.2% to 8.9%; $p < .0001$) and for dietary fiber (mean difference, 15g; 95% CI, 8.4g to 22g; $p = 0.0003$). Percent change on the pistachio diet for saturated fat intake, polyunsaturated fat intake and dietary fiber were −37%, 103% and 83%, respectively.

Lipid Values

Statistically significant differences favoring the pistachio diet were observed for HDL-C, TC/HDL-C, LDL-C/HDL-C, and B-100/A-1 (Table 3). HDL-C on the pistachio diet was 57 ± 3.5 mg/dL versus 54 ± 3.4 mg/dL on the regular diet (mean difference, 2.3; 95% CI, 0.48 to 4.0; $p = 0.02$). TC/

Table 1. Subject Values

Variables	Mean (SEM)			Difference {95% CI} Pistachio vs. Regular	p-value	Difference {95% CI} Pistachio vs. Baseline	p-value
	Baseline	Pistachio	Regular				
Age (years)	60 (2.9)	.	.	.		.	
Gender (% Male)	73%	.	.	.		.	
Weight (lbs.)	175 (6.7)	176 (6.2)	176 (6.3)	.		.	
Height (in.)	67 (1.1)	67 (1.0)	67 (1.0)	.		.	
BMI (kg/m2)	27.7 (0.90)	27.8 (0.81)	27.7 (0.82)	0.14 {−0.17, 0.45}	0.35	0.18 {−0.26, 0.62}	0.39
Blood Pressure (mm Hg)							
Systolic	129 (3.7)	128 (3.4)	125 (3.9)	2.7 {−5.4, 11}	0.49	−1.3 {−8.8, 6.2}	0.71
Diastolic	84 (2.7)	84 (2.2)	81 (2.4)	2.4 {−3.2, 8.0}	0.38	0 {−6.5, 6.5}	1.00
Pulse	78 (2.2)	76 (2.0)	75 (2.4)	1.5 {−5.7, 8.6}	0.67	−2.0 {−8.2, 4.2}	0.50

Table 2. Nutrient Values

Variables	Mean (SEM)			Difference {95% CI} Pistachio vs. Regular	p-value	Difference {95% CI} Pistachio vs. Baseline	p-value
	Baseline	Pistachio	Regular				
Nutrient Intake							
Total energy (kcal)	2120 (153)	2213 (159)	2129 (133)	84 {−130, 299}	0.41	93 {−181, 368}	0.48
Protein (%)	16 (0.69)	17 (1.2)	16 (1.6)	1.1 {−1.1, 3.3}	0.29	1.3 {−0.52, 3.2}	0.14
Carbohydrate (%)	51 (1.40)	51 (1.8)	52 (2.9)	−0.95 {−4.9, 3.0}	0.61	0.18 {−3.1, 3.5}	0.91
Fat (%)	31 (1.2)	31 (1.1)	31 (1.6)	0.73 {−2.0, 3.5}	0.58	0.80 {−2.3, 3.9}	0.59
Saturated (%kcal)	10 (0.87)	7.3 (0.68)	10 (1.8)	−2.7 {−5.4, −0.08}	0.04	−3.0 {−4.3, −1.7}	0.0002
Monounsaturated (%kcal)	11 (1.1)	11 (1.2)	11 (1.5)	0.20 {−1.3, 1.7}	0.78	0.60 {−1.2, 2.4}	0.49
Polyunsaturated (%kcal)	6.5 (0.52)	12 (1.1)	5.9 (1.1)	6.5 {4.2, 8.9}	<.0001	5.9 {4.0, 7.7}	<.0001
Fiber (gm)	21 (2.9)	33 (4.0)	18 (2.4)	15 {8.4, 22}	0.0003	12 {3.0, 21}	0.01

Table 3. Lipid Values

Variables	Mean (SEM)			Difference {95% CI} Pistachio vs. Regular	p-value	Difference {95% CI} Pistachio vs. Baseline	p-value
	Baseline	Pistachio	Regular				
Lipids (mg/dl)							
Total Cholesterol	246 (5.8)	237 (8.0)	246 (8.7)	−9.2 {−21, 2.4}	0.11	−8.9 {−19, 1.5}	0.09
Triglycerides	141 (11)	131 (11)	130 (14)	0.67 {−25, 26}	0.96	−10 {−23, 2.8}	0.11
HDL	55 (3.5)	57 (3.5)	54 (3.4)	2.3 {0.48, 4.0}	0.02	1.5 {−0.22, 3.3}	0.08
TC/HDL	4.7 (0.29)	4.4 (0.26)	4.8 (0.31)	−0.38 {−0.57, −0.19}	0.001	−0.32 {−0.55, −0.08}	0.01
LDL	164 (6.9)	148 (9.9)	163 (9.3)	−15 {−31, 0.94}	0.06	−16 {−31, −0.99}	0.04
LDL/HDL	3.1 (0.25)	2.8 (0.25)	3.2 (0.26)	−0.40 {−0.66, −0.15}	0.004	−0.39 {−0.66, −0.11}	0.009
VLDL	28 (2.2)	26 (2.2)	29 (3.2)	−2.7 {−7.1, 1.7}	0.22	−2.1 {−4.8, 0.71}	0.13
Apolipoproteins (mg/dl)							
A-1	135 (6.0)	146 (4.9)	138 (6.1)	8.0 {−3.9, 20}	0.17	11 {4.1, 18}	0.004
B-100	132 (5.3)	119 (5.5)	124 (6.0)	−5.9 {−13, 1.52}	0.11	−13 {−22, −4.6}	0.005
B-100/A-1	1.0 {0.07}	0.83 {0.05}	0.94 {0.07}	−0.11 {−0.19, −0.03}	0.009	−0.18 {−0.27, −0.10}	0.0003

HDL-C was 4.4 ± 0.26 mg/dL on the pistachio diet versus 4.8 ± 0.31 mg/dL on the regular diet (mean difference, −0.38; 95% CI, −0.57 to −0.19; p = 0.001). LDL-C/HDL-C was 2.8 ± 0.25 mg/dL on the pistachio diet versus 3.2 ± 0.26 mg/dL on the regular diet (mean difference, −0.40; 95% CI, −0.66 to −0.15; p = 0.004). B-100/A-1 was 0.83 ± 0.05 mg/dL on the pistachio diet versus 0.94 ± 0.07 on the regular diet (mean difference, −0.11; 95% CI, −0.19 to − 0.03, p = 0.009). Percent changes on the pistachio diet for HDL-C, TC/HDL-C, LDL-C/HDL-C, and B-100/A-1 were 6%, −9%, −14%, and −13%, respectively.

No statistically significant differences between the pistachio and regular diets were seen for TC, triglycerides, LDL-C, VLDL-C, or apolipoproteins A-1 and B-100. Percent changes on the pistachio diet for TC, LDL-C, VLDL-C and apolipoproteins A-1 and B-100 were −4%, −10%, −12%, 6% and −13%, respectively. However, when pistachio diet values were compared to baseline diet values, statistically significant improvements on the pistachio diet were seen for TC/HDL-C (p = 0.01), LDL-C (p = 0.04), LDL-C/HDL-C (p = 0.009), apolipoprotein A-1 (p = 0.004), apolipoprotein B-100 (p = 0.005), and B-100/A-1 (p = 0.0003). Percent changes on the pistachio diet for TC/HDL-C, LDL-C, LDL-C/HDL-C, apolipoproteins A-1 and B-100, and B-100/A-1 were −7%, −11%, −11%, 8%, −11%, and −20% respectively.

DISCUSSION

The results of this study, a randomized crossover trial conducted in fifteen free-living subjects with moderate hypercholesterolemia, add to the growing body of evidence that the consumption of a daily dose of nuts in the diet can modify serum lipids beneficially. The dietary intervention consisted of the addition of pistachios, at approximately 15% of total daily calories (about 2–3 ounces per day), which brought polyunsaturated fat intake to about 12% of total calories. Statistically significant increases were seen in HDL-C (6%, p = 0.02), and decreases in TC/HDL-C (−9%, p = 0.001), in LDL-C/HDL-C (−14%, p = 0.004), and in B-100/A-1 (−13%, p = 0.009). Decreases also were seen in LDL-C (−9%, p = 0.06). No changes in body mass index or blood pressure were observed.

While measurement of serum lipids is a recommended part of cardiovascular risk detection, the predictive value of specific lipid measures remains controversial. Kinosian et al. [57,58] and Natarajan et al. [59] have reported that changes in ratios of

TC/HDL-C and LDL-C/HDL-C are better predictors of CHD risk reduction than changes in levels. Walldius et al. [60] have reported that the apolipoprotein ratio B-100/A-1 is the best lipoprotein-related measure to estimate CHD risk. The dietary intervention did alter these ratios in a cardioprotective direction. Although the beneficial effects of pistachio consumption over the four-week intervention period were modest, it is possible that the cumulative effect of longterm consumption could prove cardioprotective and help lower coronary artery disease.

Until recently, nuts have not been considered a food to include in heart healthy diets due to their fat and calorie content. There is now a large body of epidemiological evidence demonstrating that nut consumption can reduce the risk of CHD. An inverse association between the frequency of nut consumption and the incidence of CHD mortality is supported by several large prospective studies, including the Adventist Health Study [28], the Nurses' Health Study [30], the Physicians' Health Study [31], and the Iowa Women's Health Study [32]. At least twenty clinical trials to date show that nuts reduce the concentration of serum TC and/or LDL-C when fed to healthy human subjects in controlled and/or free living settings [33–53]. Nuts are generally low in saturated fatty acids and high in unsaturated fatty acids [54]. Unsaturated fatty acids (both monounsaturated and polyunsaturated) have been shown to reduce serum TC and LDL-C.

It is plausible that the cardioprotective effect of nuts seen in epidemiological studies is due, in part, to the unsaturated fatty acid content of nuts, but these studies do not provide definitive information on the specific mechanism(s) involved. As complex plant foods, nuts contain many bioactive compounds that may play a protective cardiovascular role through mechanisms other than fatty acid content [61]. Several non-fatty acid compounds in nuts are suspected of being beneficial, including protein, dietary fiber, vitamin E, folate, magnesium, copper, zinc, potassium, phytosterols and n-3 fatty acids. Kris-Etherton *et al.* [62] have speculated that the non-lipid components of nuts may contribute to their hypocholesterolemic effect, since the observed reduction in TC and LDL-C in at least four clinical trials has exceeded that predicted by the effects of fatty acid substitution alone [7,9].

Recently revised dietary recommendations from the American Heart Association [3], US Department of Health and Human Services [5], and the National Institutes of Health's National Cholesterol Education Program [6] all emphasize unsaturated fat intake and moderate, not low, fat diets in the prevention of coronary heart disease. The American Heart Association recommends up to 20% of calories from monounsaturated fat and substituting unsaturated fat from vegetables, fish legumes and nuts [3]. In August 2002, the National Academy of Sciences (Institute of Medicine) issued a report on macronutrients, establishing dietary fat goals at a wider range, from 20% up to 35% of total calories. While there were no specific levels set for monounsaturated fat, the report did recommend switching from saturated fat to monounsaturated and polyunsaturated fats, based on their blood cholesterol lowering effect [63].

The calorie contribution of nuts to the diet has been a concern in relation to weight management, but specific studies evaluating the effects of nut consumption on weight are few. In a 30-week crossover trial involving 15 normal weight adults, Alper and Mattes found a 1.0g increase in body weight on a peanut regimen, although this increase was significantly lower than was predicted [64]. Lovejoy et al. examined the effects of 4-week almond enriched diet on insulin sensitivity in 20 free-living healthy volunteers and found that a significant decrease in total and LDL cholesterol was accompanied by a slight but significant increase in body weight in men ($\approx$0.9kg) and women ($\approx$0.3kg) [65]. In a randomized crossover study in which a free daily supplement ($\approx$320 calories) of almonds was eaten for six months, Fraser et al. found that the average weight gain ($\approx$0.40kg) for 81 subjects during the almond-feeding period was neither statistically nor biologically significant [66]. An inverse relationship between nut intake and BMI has been observed in the large epidemiological studies reported by Fraser [29] and Hu *et al.*[30]. Although not designed to produce weight loss, a large number of intervention studies [35–50, 52, 53] have not reported a weight gain, an observation also seen in our study. Finally, in a recent review, Sabaté found no direct association between weight gain and nut consumption [67].

Pistachios contain predominantly monounsaturated fat and can fit well within a heart healthy diet that includes up to 35% calories from total fat and 20% of calories from monounsaturated fat. In addition, pistachios qualify for the FDA descriptor "low saturated fat' based on containing 1.5g or less saturated fat per loz serving. Pistachios contain significant amounts of magnesium, copper and potassium, and contain the highest level of phytosterols among tree nuts (214mg/100g). The major phytosterol component is β-sitosterol (199mg/100g), which is one of several plant sterols implicated in cholesterol lowering [68]. Pistachios are a good source of dietary fiber, containing over 10% of the Daily Value in a loz serving (3g/oz, 10g/100g). In addition, pistachios are relatively high in the nonessential amino acid arginine (2.1g/21.4g protein), which appears to maintain flexible arteries and to enhance blood flow by boosting nitric oxide, a compound that relaxes blood vessels [69].

Despite the favorable changes seen in the nutrient and lipid profiles of our subjects, the findings of this study should be interpreted with caution. Firstly, the short duration of this trial does not allow us to make any inferences on the sustainability either of the improved lipid values or neutral weight gain in these subjects over longer periods of time. Secondly, it was not possible to assess whether the eating of pistachios as a snack food is sustainable over time as a healthy dietary behavior. Although there were no subject complaints during the study, a four-week trial is an insufficient interval to assess longterm acceptability. Thirdly, we could not assess how the inclusion of this single food source might alter other aspects of the diet, perhaps unfavorably. Fourthly, our small nonrandom sample should not be considered representative. Finally, we had no way of assessing or excluding such biases as clinical setting, family environment, socioeconomic status and medical comorbidity, which may have influenced our results.

In conclusion, the addition of pistachio nuts at 15% of daily fat calories (2–3 ounces per day) over a consecutive four-week period, can favorably modify lipoprotein levels in subjects with moderate hypercholesterolemia. Although modest, significant changes in a cardioprotective direction after four weeks were seen for TC/HDL-C, LDL-C/HDL-C, and B-100/A-1, important predictors of coronary heart disease, with no changes in body mass index or blood pressure. The metabolic mechanisms by which pistachios and other nuts affect serum lipid levels, the possible role played by other non-fatty acid compounds, and whether these decrease the risk of coronary heart disease, will require continuing investigation.

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