Background: Recent studies have identified potential beneficial effects of eating nuts, most of which have substantial amounts of monounsaturated fats. Macadamia nuts are 75% fat by weight, 80% of which is monounsaturated.

Objective: To examine variations in serum lipid levels in response to a high–monounsaturated fat diet based on macadamia nuts.

Methods: A randomized crossover trial of three 30-day diets was conducted in 30 volunteers aged 18 to 53 years from a free-living population. Each was fed a “typical American” diet high in saturated fat (37% energy from fat); an American Heart Association Step 1 diet (30% energy from fat); and a macadamia nut–based monounsaturated fat diet (37% energy from fat) in random order. Serum total cholesterol, high-density lipoprotein cholesterol, and triglyceride levels were measured.

Results: Mean total cholesterol level after the typical American diet was 5.20 mmol/L (201 mg/dL). After the Step 1 diet and the macadamia nut diet, total cholesterol level was 4.99 mmol/L (193 mg/dL) and 4.95 mmol/L (191 mg/dL), respectively. Low-density lipoprotein cholesterol level was 3.37 mmol/L (130 mg/dL) (typical diet), 3.21 mmol/L (124 mg/dL) (Step 1 diet), and 3.22 mmol/L (125 mg/dL) (macadamia nut diet). High-density lipoprotein cholesterol level was 1.43 mmol/L (55 mg/dL) (typical), 1.34 mmol/L (52 mg/dL) (Step 1), and 1.37 mmol/L (53 mg/dL) (macadamia nut). Lipid values after the Step 1 and macadamia nut diets were significantly different from those after the typical diet (P < .05).

Conclusions: The macadamia nut–based diet high in monounsaturated fat and the moderately low-fat diet both had potentially beneficial effects on cholesterol and low-density lipoprotein cholesterol levels when compared with a typical American diet.

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Traditionally, the inhabitants of regions such as Greece and southern Italy, where rates of coronary heart disease are low, have consumed relatively high-fat diets containing substantial amounts of olive oil, a substance with high concentrations of the monounsaturated fatty acid oleic acid.1,2 These “Mediterranean diets” frequently contain more energy from fat than the typical American diet but are higher in monounsaturated fats. Less than 10% of energy in such diets comes from saturated fats.

A number of studies have demonstrated apparently beneficial effects of diets based on high monounsaturated fatty acid content primarily derived from olive oil.3-5 Few have looked at the effects of whole complex foods high in monounsaturated fatty acids. Nuts are a complex food that contains considerable amounts of monounsaturated fat, and they have also long been part of the traditional diet in many Mediterranean countries. Recent studies have shown potential beneficial effects of tree nuts in the diet.6,7 The macadamia nut, a tree nut that originated in Australia, has become a primary export crop from Hawaii in recent years. The macadamia nut is approximately 75% fat by weight, with 88% of its energy from fat. Monounsaturated fatty acids are the predominant fat. Oleic acid is the predominant monounsaturated, but a considerable portion is palmitoleic acid, a component not present in substantial amounts in olive oil. Macadamia nuts are a complex food with large amounts of carbohydrates and fiber as well as a number of vitamins and minerals.8,9 Because of the high fat content of the macadamia nut, it has popularly been thought to be bad for health. However, since some nuts, including the macadamia nut, could be substituted for food...
items high in saturated fat as a potential element in a healthy diet, we thought it would be valuable to investigate the effects of consuming a diet with a large percentage of energy derived from macadamia nuts. We report herein the results of a carefully controlled feeding study with a crossover design comparing a diet rich in macadamia nuts with 37% energy from fat; a "typical American" diet with 37% energy from fat; and a Step 1 diet conforming to the recommendations of the American Heart Association (AHA) with 30% energy from fat.
Sixteen (53%) of the 30 participants who completed the study were white, 11 (37%) were Asian-Pacific Islanders, and 3 (10%) were black. Ages ranged between 18 and 53 years, with a mean age of 36.7 years for men and 33.8 years for women. The mean body mass index (weight in kilograms divided by the square of the height in meters) for the men was 24 ± 2.4 (range, 19.5-27.9). The mean for women was 22 ± 2.6 (range, 19.1-28.3). Only 1 subject had more than a 1.35-kg weight change during the study period (1.53-kg loss). No differences in skinfold thickness were seen throughout the study.

The mean baseline cholesterol level was 5.30 mmol/L (205.7 mg/dL) for women and 5.33 mmol/L (202.4 mg/dL) for men. The mean low-density lipoprotein cholesterol level was 3.50 mmol/L (135.2 mg/dL) for women and 3.47 mmol/L (134.2 mg/dL) for men. The mean high-density lipoprotein cholesterol level was 1.39 mmol/L (53.6 mg/dL) for women and 1.42 mmol/L (55.0 mg/dL) for men. The mean total cholesterol level was significantly lower (P<.001) and the macadamia nut (P<.001) for the macadamia nut diet. The Step 1 diet and significantly lower (P<.05) for the Step 1 diet and significantly lower (P<.05) for the macadamia nut diet. The mean HDL cholesterol level was lower after the Step 1 diet, compared with the typical American diet, the mean total cholesterol level was significantly lower (P<.001) for the macadamia nut and AHA Step 1 diets. The mean low-density lipoprotein cholesterol level was also lower for these 2 experimental diets (P<.05). Mean triglyceride values were significantly higher than with the typical American diet (P<.05) for the Step 1 diet and significantly lower (P<.05) for the macadamia nut diet. The mean HDL cholesterol level was lower after the Step 1 diet (P<.001) and the macadamia nut (P<.001) diets. When men and women were compared, lipid profile trends were not statistically different.

### Table 1. Mean Serum Concentrations of Lipids and Lipoproteins at the End of Each Dietary Period for All Subjects Combined and by Sex

<table>
<thead>
<tr>
<th>Lipid</th>
<th>Baseline Values</th>
<th>Typical American Diet</th>
<th>AHA Diet</th>
<th>Macadamia Nut Diet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Cholesterol, mmol/L</td>
<td>5.31</td>
<td>0.86</td>
<td>5.20</td>
<td>0.79</td>
</tr>
<tr>
<td>(mg/dL)</td>
<td>(205.1)</td>
<td>(33.3)</td>
<td>(201.2)</td>
<td>(30.4)</td>
</tr>
<tr>
<td>LDL, mmol/L</td>
<td>3.47</td>
<td>0.77</td>
<td>3.37</td>
<td>0.66</td>
</tr>
<tr>
<td>(mg/dL)</td>
<td>(134.0)</td>
<td>(29.8)</td>
<td>(130.4)</td>
<td>(25.7)</td>
</tr>
<tr>
<td>Triglyceride, mmol/L</td>
<td>0.91</td>
<td>0.38</td>
<td>0.87</td>
<td>0.37</td>
</tr>
<tr>
<td>(mg/dL)</td>
<td>(80.2)</td>
<td>(33.1)</td>
<td>(77.5)</td>
<td>(32.7)</td>
</tr>
<tr>
<td>HDL, mmol/L</td>
<td>1.42</td>
<td>0.18</td>
<td>1.43</td>
<td>0.20</td>
</tr>
<tr>
<td>(mg/dL)</td>
<td>(55.0)</td>
<td>(6.8)</td>
<td>(55.3)</td>
<td>(7.6)</td>
</tr>
</tbody>
</table>

* AHA indicates American Heart Association; LDL, low-density lipoprotein; and HDL, high-density lipoprotein.
†P<.01 vs typical American diet.
‡P<.05 vs typical American diet.
§P<.001 vs typical American diet.

### RESULTS

The mean total cholesterol level was significantly lower (P<.001) for the macadamia nut diet.

When the mean cholesterol trends for each of the 6 randomization sequences were examined, there was a tendency for total cholesterol level to drop during the study period, in all randomization groupings, a phenomenon...
that is common in individuals who become involved in studies in which their diets are controlled to a greater extent than in a free-living environment.14 These trends did not exceed expectations, and there were no significant carryover effects between dietary periods. Adjustment for period effects demonstrated only minimal effects.

### Table 2. Energy Content and Nutritional Profile of Macronutrients as Planned and as Observed From Chemical Analyses of 12 Complete-Day Samples*

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>% of Energy Intake</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Typical American Diet</td>
</tr>
<tr>
<td></td>
<td>Planned</td>
</tr>
<tr>
<td>Protein</td>
<td>17</td>
</tr>
<tr>
<td>Carbohydrate</td>
<td>46</td>
</tr>
<tr>
<td>Total fat</td>
<td>37</td>
</tr>
<tr>
<td>Saturated</td>
<td>16</td>
</tr>
<tr>
<td>Polysaturated</td>
<td>7</td>
</tr>
<tr>
<td>Monounsaturated</td>
<td>14</td>
</tr>
<tr>
<td>Energy, kJ</td>
<td>13 422</td>
</tr>
<tr>
<td>Cholesterol, mg</td>
<td>300</td>
</tr>
</tbody>
</table>

*Diets were formulated and nutrients calculated by Genesis Software Version 4.2 from ESHA Research, Portland, Ore. AHA indicates American Heart Association.

The 3 diets used in this investigation were designed both to evaluate substitution of monounsaturated fat (primarily derived from macadamia nuts) for saturated fat and to compare the high–monounsaturated fat diet with the lower-fat AHA Step 1 diet. The findings indicate that the macadamia nut–based high-fat (37%) diet and the moderately low-fat (30%) AHA Step 1 diet had similar effects on lipid profiles. The results suggest that replacing saturated fats in the typical American diet with monounsaturated fats present in macadamia nuts has a favorable effect on serum cholesterol concentrations of healthy adults. This effect was seen despite the fact that the study included a wide range of ethnic groups, had a broad age range, and included only relatively lean, healthy individuals of both sexes, many of whom had relatively low cholesterol concentrations. It should be noted that simply adding foods high in monounsaturated fats to the diet instead of substituting for foods high in saturated fats could be deleterious because of the adverse effects associated with weight gain. It is of interest that the results of the study were similar in men and women. Although women appeared to have somewhat greater lowering of cholesterol and low-density lipoprotein cholesterol levels with the experimental diets, the small sex-specific sample sizes may have contributed to these findings, and caution must be used in interpretation of the sex-specific results. Most previous studies either have been done only in men or have not reported sex-specific findings. These data would be most appropriately viewed as generating hypotheses for use in future investigations. A 30-day diet period is the minimum that should be used to see dietary effects on lipids. It is possible that the differences seen herein would be increased with a longer period for each diet.

Making direct comparisons between studies is difficult because of widely variable differences in the length of studies, the characteristics of the participants, and the range of fat, cholesterol, and fiber contents of diets used in the various studies. However, the results of this study are generally consistent with those seen in other studies contrasting high–monounsaturated fat diets to high–saturated fat and low–fat diets.15–23 The magnitude of the decrease of serum cholesterol level with both the moderately low-fat and the high–monounsaturated fat diets in this study is lower than in some studies. On the other hand, the decrease in triglyceride levels with the macadamia nut diet is larger than that reported in most other similar studies. The 4.5% lower HDL cholesterol level with the macadamia nut diet compared with the high-fat diet is greater than the changes seen in some other published studies, which generally report anywhere from a 2% increase to a 6% drop.15–23 The differences in lipid levels, including those in HDL cholesterol level, are similar to those seen in the recently reported Dietary Effects on Lipoproteins and Thrombogenic Activity (DETA) study, which also compared diets that replaced saturated fats with monounsaturated fats or carbohydrates and that had a nutrient profile similar to that used in this study.23 Such changes in HDL cholesterol level are significant and potentially important. However, Hegsted et al.10 pointed out that the effects of diet on HDL cholesterol level are complex and may not be subject to meaningful interpretation. Thus, interpretation of the HDL results of the present study may also be difficult. In general, the changes in HDL cholesterol level induced by diet are relatively small, the day-to-day variation is large, and the clinical significance of such changes is not known.24 Further investigation of HDL effects is longer-term studies with close attention to other dietary components is warranted.

Given the data available on the effects of monounsaturated fats in the diet and the nutrient composition of the macadamia nut, a beneficial effect could be hypothesized. However, nuts are complex foods that contain many nutrients, and macadamia nuts have a fatty acid profile that differs somewhat from that of most common sources of monounsaturated fatty acids in the diet. One of these monounsaturated fatty acids, palmitoleic acid, was reported to increase cholesterol level in one study.23 The current study was not designed to examine the effects of individual fatty acids, but the overall ef-
fect of the macadamia nut–based diet was within the range of that seen in other short-term feeding studies. In addition, the magnitude of the cholesterol-lowering effect of a diet high in monounsaturated fatty acids is similar to that of a Step 1 diet as seen in other such studies.

An epidemiological study of California Adventists was one of the first to suggest the potential health benefits of nuts.26 That study suggested that regular consumption of nuts had a protective effect against coronary heart disease in that population. Dietary studies of the walnut and the almond have provided more specific evidence of the potential cholesterol-lowering properties of this group of foods.6,8 As with all high-fat foods, nuts may be an important source of energy, and, if not substituted for other fatty foods, they could result in weight gain.

However, in a pilot study for the present study in which 70 healthy free-living subjects were randomized to groups given supplements of 90 g (2688 kJ) or 45 g (1344 kJ) of macadamia nuts as a supplement, or to a regular diet group, there was no significant change in the mean weight of any of the groups after 1 month.27 All groups received only a single 15-minute dietary counseling session on food substitutions to avoid weight gain and eating a healthy diet. Some participants in that study reported a suppression of appetite after eating their nuts each day. Eating nuts may be associated with increased satiety, but few data are available.

No important side effects of consistent ingestion of large amounts of macadamia nuts were noted in either the pilot study or the feeding study. In the pilot study, gastrointestinal tract discomforts consistent with those experienced with radical shifts in dietary fat content were not uncommon but usually temporary. There was no difference in serum cholesterol level between the groups in the pilot study, although the high-dose macadamia nut group ate 50% of their energy as fat.

In conclusion, the results of this study indicate that the consumption of a diet high in monounsaturated fats, a significant proportion of which were derived from macadamia nuts, appears to lower serum cholesterol level when total energy balance and percentage of energy from fat are maintained. In addition, the effect of such a diet on levels of cholesterol and other lipids was not statistically different from that seen with a lower-fat AHA Step 1 diet, except for lowering of triglyceride levels by the macadamia nut–based diet. These results, coupled with the palatability of macadamia nuts, suggest that physicians can recommend the consumption of these and other nuts as part of a satisfying and healthy diet.

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REFERENCES