Impact of Dietary Patterns and Interventions on Cardiovascular Health

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Dietary recommendations are a key element in the management of cardiovascular disease. Evidence is mounting that certain dietary patterns can influence cardiovascular health by modifying risk factors such as obesity, dyslipidemia, and hypertension, as well as factors involved in systemic inflammation, insulin sensitivity, oxidative stress, endothelial function, thrombosis, and cardiac rhythm.1,2 In recent years, numerous dietary fads have emerged, in part as a response to the rising prevalence of obesity in the United States.3 In the present study, we review the various dietary portfolios that have emerged in the literature and the major studies that investigated their effectiveness in modifying cardiovascular risk.

Description of Some Traditional and Popular Diets

Currently, the typical American diet is estimated to derive 49% of its calories from carbohydrates, 34% from fat, and 12% to 16% from protein.4 Proposals to alter the proportions and/or types of macronutrients in this diet have been made for weight loss and cardiovascular health (Table 1).5–12 For weight management, for example, the strategy recommended by most medical groups entails the intake of a low-calorie, low-fat diet. The concept of fat restriction for weight management stems from traditional calorimetric measurements, which assign greater energy values to fat (9 kcal/g) and less to carbohydrate and protein (4 kcal/g). The low-calorie concept, on the other hand, is an intuitive technique to induce negative energy balance and has been adopted by some commercialized weight loss programs such as Weight Watchers International.

One alternative proposed for weight loss is the low-carbohydrate diet. This was first described by William Banting13 in the 1860s and recently has received much attention in the form of the Atkins’, Stillman, Protein Power Lifeplan, and Zone diets. The Atkins’ diet begins with the carbohydrate restriction phase. The carbohydrate restriction phase is followed by carbohydrate re-introduction phases. Both methods also strongly recommend other intensive lifestyle changes such as exercise and stress management.

Very-low-fat diets were popularized by Nathan Pritikin9 in the 1970s and later by Dean Ornish.10 Both methods use variations of the vegetarian diets and restrict fat to <15% of total calories, as opposed to the ATP III recommendations, which allow 25% to 35% of total calories to come from fat.5 Both methods also strongly recommend other intensive lifestyle changes such as exercise and stress management.

Enriching diets with polyunsaturated fatty acids (PUFAs) in place of saturated fats has been studied extensively. From a cardiovascular standpoint, the important dietary PUFAs include the n-3 PUFAs, particularly the long-chain eicosapentaenoic acid (EPA:20:5n3) and docosahexaenoic acid (DHA:22:6n3) and the intermediate-
chain alpha-linolenic acid (ALA:18:3n3), which is vari-
ably converted to EPA or DHA. ALA is found in canola,
soybean, flaxseed, and walnut oil; nuts; and vegetables
of the cabbage family. EPA and DHA are obtained pri-
marily from fatty fish, especially salmon and anchovy
(each with ∼1.7 g of n-3 PUFAs per 100-g portion), sardines, herring,
mackerel, and lake trout. The interest in n-3 PUFAs dates
back to the late 1970s, when Dyerberg and coworkers16
demonstrated low rates of coronary events in Greenland
Eskimos whose diet consisted mainly of fish and seal. The
other major class of PUFAs is the n-6 PUFAs. In the
Western diet, the principal n-6 PUFA is linoleic acid
(LA:18:2n6), which comes from safflower, sunflower,
and corn oils.

The Mediterranean diet bears some semblance to diets
enriched with monounsaturated fatty acids (MUFA),
PUFAs, and n-3 PUFAs. The impetus behind its popularity
stems from the Seven Countries Study initiated by Ancel

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TABLE 1. Various Dietary Patterns, Including Those Popularized Commercially and Those Investigated by Observational Studies and Clinical Trials

<table>
<thead>
<tr>
<th>Diet Description*</th>
<th>Description*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average American diet</td>
<td>CHO 49%, fat 34%, protein 12%–16%</td>
</tr>
<tr>
<td>ATP III recommendations</td>
<td>CHO 50%–60%</td>
</tr>
<tr>
<td>Saturated fat &lt;7% of total calories</td>
<td>PUFA up to 10% of total calories</td>
</tr>
<tr>
<td>MUFA up to 20% of total calories</td>
<td>Cholesterol &lt;200 mg/d</td>
</tr>
<tr>
<td>Protein 15%</td>
<td>Fiber 20–30 g/d</td>
</tr>
<tr>
<td>Total calories should be balanced against daily energy expenditure to maintain desirable body weight</td>
<td></td>
</tr>
<tr>
<td>Weight Watchers diet</td>
<td>Reduction in dietary portion sizes and total caloric intake</td>
</tr>
<tr>
<td>Low-carbohydrate diets</td>
<td>CHO 5%, fat 68% (saturated fat 26%), protein 27%†</td>
</tr>
<tr>
<td>Atkins’ diet</td>
<td>CHO 3%, fat 33% (saturated fat 13%), protein 64%†</td>
</tr>
<tr>
<td>Stillman diet</td>
<td>CHO 16%, fat 54% (saturated fat 18%), protein 26%†</td>
</tr>
<tr>
<td>Zone diet</td>
<td>CHO 36%, fat 29% (saturated fat 9%), protein 34%†</td>
</tr>
<tr>
<td>Diets based on GL</td>
<td>Up to 30%–40% CHO, but only those with GI &lt;35 allowed during weight-losing phase; more emphasis on GL in subsequent phases</td>
</tr>
<tr>
<td>Montignac’s diet</td>
<td>52% CHO (emphasis on CHO with low GI), fat 21% (saturated fat 4%), protein 27%†</td>
</tr>
<tr>
<td>Sugar Busters diet</td>
<td>Extreme CHO restriction for 2 wk, followed by reintroduction of CHO with low GI; also encourages intake of MUFA, PUFAs, fiber, and lean protein</td>
</tr>
<tr>
<td>South Beach diet</td>
<td>Allows only foods from plants such as fruits, vegetables, legumes, grains, seeds, and nuts; all forms of animal products (including dairy, eggs, and honey) are not allowed</td>
</tr>
<tr>
<td>Protein Power diet</td>
<td>Similar to vegan diet but dairy products allowed</td>
</tr>
<tr>
<td>Lacto-ovo-vegetarian diet</td>
<td>Similar to vegan diet, but dairy products and eggs allowed</td>
</tr>
<tr>
<td>Very-low-fat diets</td>
<td>Variation of vegetarian diet. Fat &lt;15%</td>
</tr>
<tr>
<td>Pritikin diet</td>
<td>Variation of vegetarian diet. Fat &lt;15%</td>
</tr>
<tr>
<td>Ornish diet</td>
<td>Fat 35%–46%, PUFA 13%–21%, saturated fat 9%, or PUFA-to-saturated fat ratio of 2</td>
</tr>
<tr>
<td>Diet enriched with PUFAs</td>
<td>1-1.8 g/d of EPA/DHA or 2–3 g/d ALA</td>
</tr>
<tr>
<td>Mediterranean diet</td>
<td>Abundance of plant food (vegetables, legumes, fruits, nuts, and whole-grain cereals)</td>
</tr>
<tr>
<td>Olive oil as the principal source of fat</td>
<td>Moderately high intake of fish</td>
</tr>
<tr>
<td>Relatively low intake of meat and poultry</td>
<td>Moderate consumption of wine, generally with meals</td>
</tr>
<tr>
<td>DASH diet</td>
<td>High intake of fruits, vegetables, and low-fat dairy products; low intake of total fat, saturated fat, and cholesterol; sodium ~3 g/d</td>
</tr>
</tbody>
</table>

CHO indicates carbohydrate; GL, glycemic load.
*Percentages in macronutrient composition pertain to percentages of total caloric intake.
†Three-day average composition of the diet.
Diets and Lipids

Dyslipidemia has been linked to insulin resistance and complementary hyperinsulinemia. Along these mechanisms, some studies suggested that high-carbohydrate diets may promote dyslipidemia. One small randomized, crossover study associated a high-carbohydrate diet with higher fasting triglyceride and lower high-density lipoprotein (HDL) levels. This unfavorable effect of carbohydrates on lipids was further tested by 4 randomized trials that compared low-carbohydrate with low-fat diets in overweight/obese subjects (Table 2). Three of the trials showed a more impressive increase in HDL levels with a low-carbohydrate diet, whereas 2 demonstrated a greater decrease in triglyceride levels with this diet. The effect of GI on serum lipids has likewise been investigated (Table 2). Two cross-sectional surveys, the British Adult Survey and the Third National Health and Nutrition Examination Survey, showed an inverse correlation between GI and HDL levels. These correlations, however, were not supported by a 10-year observational study of elderly Dutch men in which GI did not correlate with total cholesterol, HDL, or triglyceride levels.

Studies on very-low-fat diets and serum lipids have been conducted, although the intervention often involved a holistic, multifactorial approach (Table 2). In the Ornish Lifestyle Heart Trial, 48 men with moderate to severe coronary artery disease (CAD) were randomized to usual care or intensive lifestyle changes (vegetarian diet with fat restricted to 10% of total calories, moderate aerobic exercise, stress management training, smoking cessation, and group psychosocial support). After 1 year, there was a significant reduction in the low-density lipoprotein (LDL) level of the group that underwent intensive lifestyle changes compared with the group assigned to usual care (40% versus 1%). Multiple studies, however, have shown that the type of fat in the diet can affect serum lipids to a greater degree than the absolute amount of fat. Trans MUFA s, saturated fatty acids, and dietary cholesterol result in unfavorable lipid profiles. Trans fatty acids, derived largely from the industrial hydrogenation of PUFAs, raise LDL and lipoprotein(a) levels and decrease HDL levels. Saturated fatty acids increase LDL and HDL levels. Dietary cholesterol can increase total cholesterol and LDL levels, although to a lesser extent than saturated fatty acids. On the other hand, the cis MUFA s and PUFAs affect the lipid profile favorably by lowering LDL and raising HDL levels.

Recently, much attention has been given to the potential role of soy protein and isoflavones in cholesterol lowering. In a meta-analysis of 29 controlled studies, soy protein was shown to lower cholesterol levels by an order of 20% when the initial level was >335 mg/dL and to a lesser degree when the initial level was only mildly elevated. The cholesterol-lowering effect of soy protein is thought to be related to alterations in the amino acid composition of the diet or in bile acid/cholesterol absorption, an increased turnover of the very-LDL apolipoprotein B, or increased LDL receptor activity. Many of the soy products such as tofu, soy butter, and soy nuts also have high contents of PUFAs and fiber and a low content of saturated fat. In a review of soy protein trials by the American Heart Association Nutrition Committee, ingestion of soy protein (25 to 135 g/d) containing isoflavones (40 to 318 mg/d) was associated with a 3% weighted average reduction in LDL and non-HDL cholesterol levels; the effects on HDL and triglyceride levels were small (1.5% and −5%, respectively) and not significant in most studies. In 19 studies that tested the effect of isoflavones on lipids, the weighted average reduction in LDL was 0%. Thus, current evidence favors soy protein, not soy isoflavones, as the important factor in LDL lowering.

Since the 1950s, dietary plant sterols and their saturated counterparts, stanols, have been recognized to lower cholesterol levels. More recently, an analysis of randomized trials of polyunsaturated margarines with and without added plant sterols/stanols demonstrated a dose-response relation between plant sterols/stanols and LDL reduction for up to a daily dose of 2 g. At doses of ≥2 g/d, the LDL reduction was 21 mg/dL in individuals 50 to 59 years of age and slightly less in younger individuals. Overall, the numbers translated to a 9% to 14% reduction in LDL. Notably, the average Western diet contains only 200 to 400 mg/d of plant sterols, whereas vegetarian diets could contain as much as twice this amount. To boost the dietary intake of these substances, some manufacturing companies of table spreads and margarines have begun to incorporate esterified plant sterols and stanols into their products. The effectiveness of these substances was underscored by the ATP III report in 2001 that recommended them as dietary adjuncts for lowering LDL. Their hypcholesterolemic effect is believed to result from the reduction in intestinal absorption of dietary and biliary cholesterol as a result of displacement of cholesterol from mixed micelles and/or an increase in the expression of the adenosine triphosphate–binding cassette A1 transporter in enterocytes.

Most of the data on high-fiber intake point to a beneficial effect on total cholesterol and LDL levels. Although a variety of dietary sources, including fruits, vegetables, cereal products, and legumes, provide different types of fiber, soluble fiber has been well associated with cholesterol reduction. One meta-analysis associated the intake of 3 g/d of soluble fiber with a 5-mg/dL reduction in total cholesterol and LDL levels. In addition, oat products appear to decrease the concentration of small, dense LDL particles. The cholesterol-lowering effect of fiber is believed to be a result primarily of its ability to act as a bile acid sequestuant. Furthermore, fiber appears to slow gastric emptying and glucose absorption, thereby decreasing the degree of insulin response to a meal and subsequent hepatic lipogenesis.
### Diets and Body Weight

Although restriction of caloric intake below the level of energy expenditure is an intuitive strategy to achieve weight loss, the effect of changes in dietary macronutrient composition has been a subject of greater controversy. The 4 randomized trials that compared low-carbohydrate with low-fat diets in overweight/obese patients showed that in each dietary group, significant weight loss was achieved at 6 months and 1 year (Table 2).19–22 In all trials, a significantly greater amount of weight loss occurred in the low-carbohydrate group at 6 months. However, in the 2 trials carried out for 1 year, no significant difference in weights was detected between the 2 groups at 1 year. On the basis of these results, a low-carbohydrate diet appears more effective than a low-fat diet in causing short-term, albeit sustained, weight loss. One mechanism by which low-carbohydrate diets induce immediate weight loss is believed to be ketosis-induced diuresis and loss of appetite.42 This hypothesis, however, has

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<table>
<thead>
<tr>
<th>Type of Diet</th>
<th>Study or Author</th>
<th>Type of Study</th>
<th>Patients</th>
<th>Duration</th>
<th>Dietary Intervention</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-carbohydrate diet</td>
<td>Foster et al23</td>
<td>Randomized trial</td>
<td>63 Obese men and women</td>
<td>1 y</td>
<td>Atkins’ diet vs low-fat diet (60% CHO, 15% protein, 25% fat)</td>
<td>Low-CHO group had significantly greater increase in HDL and decrease in TG. Within each group, significant weight loss was achieved. The difference in weight loss between the two groups was not significant at 1 year.</td>
</tr>
<tr>
<td>Low-carbohydrate diet</td>
<td>Stern et al20</td>
<td>Randomized trial</td>
<td>132 Obese patients</td>
<td>1 y</td>
<td>Low-CHO diet (&lt;30 g CHO/d) vs calorie-restricted low-fat diet (&lt;1800 calories/d, &lt;30% fat)</td>
<td>Low-CHO group had significant decrease in TG and less decrease in HDL. Significant weight loss was achieved within each group. The difference in weight loss between the 2 groups was not significant.</td>
</tr>
<tr>
<td>Low-carbohydrate diet</td>
<td>Brehm et al21</td>
<td>Randomized trial</td>
<td>53 Obese women</td>
<td>6 mo</td>
<td>Low-CHO diet &lt;30% of calories from fat, &lt;10% saturated fat, &lt;300 mg cholesterol/d</td>
<td>Low-CHO diet had greater increase in HDL. Within each group, significant weight loss was achieved. The difference in weight loss between the 2 groups was significant (P&lt;0.001).</td>
</tr>
<tr>
<td>Low-carbohydrate diet</td>
<td>Yancy et al22</td>
<td>Randomized trial</td>
<td>120 Overweight and hyperlipidemic patients</td>
<td>6 mo</td>
<td>Low-CHO diet (&lt;20 g CHO/d) vs low-fat diet (&lt;30% of calories from fat, &lt;10% saturated fat, &lt;300 mg cholesterol/d)</td>
<td>Low-CHO diet had greater increase in HDL and decrease in LDL, but this was confounded by nutritional supplements, eg, fish oil, given to low-CHO group.</td>
</tr>
</tbody>
</table>

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CHO indicates carbohydrate; TG, triglycerides; and DM, diabetes mellitus.
been questioned by Foster and coworkers. Alternative mechanisms to explain the weight loss from low-carbohydrate diets have included the highly restricted food choices that come with the simplistic design of the diet and the appetite-suppressing or satiety-inducing properties of the diet.

The impact of low-GI diets on weight has been examined by only a few interventional studies, most of which were short term. The longest of these was a 12-week crossover study that suggested a slightly greater amount of weight loss with a low-GI diet than with a conventionally balanced diet. Two other studies of much shorter duration failed to demonstrate any significant effect of GI on weight.

One randomized trial compared the effectiveness of the Atkins’, Zone, Weight Watchers, and Ornish diets in inducing weight loss (Table 2). At the end of 1 year, dietary adherence ranged between 50% and 65%. Modest weight loss, ranging from 2.1 to 3.3 kg, was achieved by the subjects in each dietary group. Interestingly, the degree of weight loss correlated not with diet type but rather with the degree of adherence to whichever diet the subjects were assigned.

The consumption of high-fiber, whole-grain foods has been shown to correlate inversely with the degree of weight gain over time, in contrast to the consumption of refined-grain foods. In a prospective study of >74 000 female nurses who were followed up for 12 years, those who consumed more whole grains consistently weighed less than those who consumed fewer whole grains. Furthermore, those with the greatest increase in fiber consumption gained ~1.5 kg less than those with the least consumption, independently of initial body weight and age.

Epidemiological studies have likewise suggested an inverse correlation between nut and seed consumption and body mass index. Well-controlled nut-feeding trials, on the other hand, demonstrated no changes in body weight with nut consumption. Both of these findings seem counterintuitive given the fatty and calorie-dense nature of nuts and seeds, but rationalizations have been proposed. Weight loss, for example, may be promoted by the incomplete digestion of nuts and seeds and subsequent enhancement of satiety. Some evidence also indicates that individuals on nut-rich diets excrete more fat in stools.

**Diets and Inflammatory Markers/Atherosclerosis**

Markers of inflammation such as C-reactive protein (CRP), interleukin-6 (IL-6), tumor necrosis factor alpha-α (TNF-α), soluble TNF-α receptor types 1 and 2, and fibrinogen have been positively associated with cardiovascular risk. Investigating the effects of specific dietary components on these markers has been an area of substantial interest. Several studies have demonstrated an inverse association between the n-3 PUFAs, ALA, EPA, and DHA and serum levels of inflammatory markers in healthy individuals and those with stable CAD. Clinical trials that investigated the effect of EPA and DHA on angiographic CAD, however, have yielded mixed results. In the Shunt Occlusion Trial, 610 patients undergoing coronary artery bypass grafting were randomized to a fish oil group (4 g/d fish oil concentrate) or a control group. At 1 year, the vein graft occlusion rate was significantly lower in the fish oil group (27% versus 33%). In another trial, 223 CAD patients were randomized to receive fish oil capsules or capsules of PUFAs in the average European diet. After a 2-year period, intake of fish oil capsules resulted in more coronary lesions that displayed mild to moderate regression. In contrast to these data, a study that randomized 551 patients undergoing elective coronary angioplasty to capsules of n-3 PUFAs (5 g/d) or capsules of corn oil showed comparable restenosis rates at 6 months after angioplasty.

The impact of very-low-fat diets on atherosclerosis has been investigated by at least 2 interventional studies. In the Heidelberg trial, 113 patients with stable angina were randomized to a very-low-fat diet (fat <20% of total calories and total cholesterol <200 mg/d) plus moderate-intensity exercise or usual care by their private physician. At the end of 1 year, there was significantly less progression of coronary lesions in the intervention group. In the Ornish Lifestyle Heart Trial in which 48 men with moderate to severe CAD were enrolled, 35 men completed the 5-year follow-up quantitative coronary angiography. No lipid-lowering drug was used by any of the participants assigned to intensive lifestyle changes. After 5 years, the average diameter stenosis decreased by 3.1 absolute percentage points in the experimental group and increased by 11.8 percentage points in the usual-care group. Although both trials showed impressive results, it should be noted that both used a multifactorial approach to lifestyle changes.

Like the n-3 PUFA–rich diets, dietary fiber was inversely associated with CRP levels in 2 observational studies. A possible antiinflammatory property of fiber also has been supported by atherosclerosis data. A prospective cohort study of >500 individuals 40 to 60 years of age showed that the intake of viscous fiber, especially pectin, protected against the progression of intima-media thickness of the common carotid arteries. Another prospective cohort study of postmenopausal women with CAD showed that increased intake of cereal fiber and whole-grain products was associated with less progression of coronary artery stenosis.

The consumption of nuts and seeds appears to have its own merits as well. In hypercholesterolemic individuals, when walnuts were substituted for MUFAs in a Mediterranean diet, endothelium-dependent vasodilation improved. Similarly, in the >6000 participants of the Multi-Ethnic Study of Atherosclerosis, frequent nut and seed consumption correlated inversely with CRP, IL-6, and fibrinogen levels, especially in whites.

As with most of its individual components, the Mediterranean diet has been demonstrated to reduce markers of inflammation and to improve endothelial function. In an Italian trial in which 180 patients with metabolic syndrome were randomized to the Mediterranean diet or a prudent diet and followed up for 2 years, those instructed to follow the Mediterranean diet had significantly lower CRP, IL-6, IL-7, and IL-18 levels and significantly improved endothelial scores. The same group of patients achieved a significantly greater amount of weight loss. Interestingly, low-calorie diets that are successful in inducing weight loss appear effective in lowering CRP levels, almost regardless of diet composition.
In keeping with these results, low-fat diets that fail to induce weight loss do not appear to affect CRP concentrations in overweight individuals.61

More recently, a randomized controlled trial involving 101 patients with established CAD showed that the Mediterranean diet, when consumed in the background of the current treatment for CAD, did not have a significant impact on the serum concentrations of high-sensitivity CRP, cholesterol, triglyceride, fibrinogen, homocysteine, and fasting insulin.62 In this trial, 80% of the patients were taking a statin, which is known to lower serum markers of inflammation. Thus, it is plausible to assume that the widespread use of drugs like aspirin and statins by patients with CAD may mask any independent effect of the Mediterranean diet on inflammatory markers.

Diets and Hypertension

Epidemiological studies have suggested that vegetarians tend to have lower blood pressures than nonvegetarians.63 This finding was subsequently supported by clinical trials that showed that replacing animal products with vegetable products decreased blood pressure in both normotensive and hypertensive individuals.64,65 An extension of this concept was established by the Dietary Approaches to Stop Hypertension (DASH) Trial in which 459 adults with systolic and diastolic blood pressures <160 mm Hg and 80 to 95 mm Hg, respectively, were randomized to 3 diets: a control diet that typified the average American diet, a diet that provided more fruits and vegetables and fewer snacks and sweets but was otherwise similar to the control diet, and the DASH diet.12 The latter was rich in fruits, vegetables, and low-fat dairy products and low in total fat, saturated fat, and cholesterol. The sodium content of all diets was ≈3 g/d. Compared with the control group, the fruits-and-vegetables group and the DASH group achieved significantly greater reductions in systolic and diastolic blood pressures. The greatest impact was seen in the DASH group, which had a reduction in systolic and diastolic blood pressures that were 5.5 and 3.0 mm Hg more than those achieved in the control group. This antihypertensive effect was maximal by the end of the second week of the trial and was maintained for 8 weeks.

Reduction in dietary sodium intake also has been shown to lower blood pressure. The Trial of Nonpharmacologic Interventions in the Elderly (TONE) was a randomized controlled trial conducted among elderly individuals 60 to 80 years of age with mild hypertension. After 29 months of follow-up, the study demonstrated that a reduction in dietary sodium, confirmed by a decrease in urinary sodium excretion, led to more effectively controlled blood pressures. In fact, discontinuation of antihypertensive drug therapy was possible in a greater percentage of patients assigned to sodium restriction than those under usual care.66,67 Similarly, a follow-up study to DASH, the DASH-Sodium Trial, showed that blood pressure can be lowered in consumers of either the control diet or the DASH diet if the sodium intake was reduced from a high level (3.5 g/d) to an intermediate level (2.3 g/d) or even from an intermediate level to a lower level (1.2 g/d).68

Among obese hypertensive individuals, weight loss promotes better blood pressure control. This was shown in the TONE trial in which 585 of the elderly participants were obese.66 Those randomized to interventions that promoted weight loss achieved 3.5- to 4.5-kg reductions in weight, whereas those not assigned to weight loss achieved only a 0.9-kg average reduction. Compared with the latter, those in the weight-loss group had greater reductions in their systolic and diastolic blood pressures (−4.0 and −1.1 mm Hg, respectively).

Diets and Heart Failure

For patients with heart failure, the traditional dietary recommendations consist of restricting sodium intake to 2 to 3 g/d, restricting water in those who have concurrent hyponatremia, restricting alcohol consumption, and promoting weight loss in obese individuals. These recommendations are based mainly on observational studies and physiological principles rather than randomized controlled trials.

Currently, no evidence indicates that dietary sodium restriction alone decreases morbidity and mortality from heart failure. Nonetheless, studies have shown that sodium restriction can control some risk factors of heart failure, including hypertension66–68 and left ventricular hypertrophy.69 Conversely, increased dietary sodium may be a risk factor for heart failure in overweight subjects. In a 19-year follow-up of 5129 overweight men and women in the First National Health and Nutrition Examination Survey Epidemiology Follow-Up Study, the relative risk of heart failure was 1.43 (95% CI, 1.07 to 1.91) for those whose sodium intake was >2.6 g/d compared with those whose intake was below 1.2 g/d.70 Evidence suggests that obesity increases the risk for heart failure and risk of death proportionately to the degree of obesity.71–73 In the Framingham Heart Study, for example, each increment of 1 in body mass index resulted in an increase in the risk of heart failure of 5% among men and 7% among women. After heart failure has set in, however, the impact of being overweight or obese is less clear. Although weight loss among morbidly obese patients with heart failure has been reported to improve functional capacity,74 emerging data indicate that an overweight or obese status compared with normal weight or cachexia leads to longer survival rates among heart failure patients.74–75 This could be due to the attenuation of cytokines by elevated serum lipoproteins, neutralization of harmful TNF-α by soluble TNF-α receptors derived from adipose tissue, and a tempered activation of the sympathetic nervous and renin-angiotensin-aldosterone systems.74 Fewer studies have been performed on how weight affects left ventricular diastolic dysfunction, although a suggestion has been made that long-term caloric restriction can attenuate the age-related changes in diastolic function.76

Diets and Outcomes in Patients With Cardiovascular Disease

Carbohydrate-Modified Diets

A meta-analysis of studies that prospectively monitored blood glucose levels and cardiovascular disease in nondiabetic individuals revealed that subjects with the highest postchallenge glucose had a 27% higher risk for cardiovascular disease than those with the lowest postchallenge glu-
Recent observational studies (Table 3) demonstrated that the total amount of fat intake is not as important for cardiovascular health as the type of fat. In the Seven Countries Study, the total fat intake of the population in Crete was high (mainly MUFA), whereas that of the population in Japan was low, yet both countries had low incidences of coronary events. Similarly, the Greenland Eskimos have been shown to have a low incidence of coronary events despite their fat-rich diet. This is now believed to be a result of the cardioprotection afforded by the n-3 PUFAs in the Eskimo diet.

At least 4 studies have demonstrated that enriching diets with PUFAs provides cardiovascular benefit (Table 3). The Finnish Mental Hospital Study, 84 Wadsworth Veterans Administration Hospital Study, 85 Paul Leren Oslo Study, 86 and British Medical Research Council soybean oil trial 87 have all shown that PUFA-enriched diets can decrease coronary event rates by 12% to 44% over a 5- to 8-year period. Notably, these studies did not use low-fat diets; in fact, 35% to 46% of the total caloric intake was allocated to fat. The Minnesota Coronary Survey was 1 study on PUFA-enriched diets that failed to reveal a significant reduction in cardiovascular outcomes; the null result could have been due to the relatively short duration of the study. 88

Two large randomized trials, namely the Diet and Reinforcement Trial (DART) 89 and Gruppo Italiano per lo Studio della Sopravvivenza nell'Infarto Miocardio (GISSI)-Prevenzione trial, 90 focused on diets enriched with n-3 PUFAs and showed that in post-myocardial infarction (MI) patients, they conferred significant reductions in cardiovascular mortality, on the order of 30%. These findings were consistent with those obtained from large observational studies 97–100 and a meta-analysis of randomized controlled trials on n-3 PUFAs by Bucher and coworkers. 101

More recently, the Japan EPA Lipid Intervention Study (JELIS) showed that in hypercholesterolemic individuals, high-dose EPA reduced major coronary events, primarily unstable angina and nonfatal MI, by 19% after 4.5 years of follow-up. 91 Because the intervention and control groups did not have any significant difference in LDL or HDL levels after treatment, the benefit from EPA was thought to be independent of cholesterol. In contrast to these findings, the meta-analysis of randomized controlled trials and cohort studies by Hooper and coworkers 102 suggested that n-3 PUFAs, in the form of supplements or obtained naturally from fish intake, afforded very little to no benefit in terms of mortality or cardiovascular event risk reduction.

Data from the GISSI-Prevenzione trial had suggested that fish oil supplements led to a significant reduction in the risk of sudden cardiac death among patients with a recent MI. It has been further proposed that n-3 PUFAs affect sodium and calcium channels in a manner that decreases myocardial excitability and cytosolic calcium fluctuations, 103 and enrichment of membrane phospholipids with these PUFAs may reduce the risk of fatal arrhythmias. 99 Data from JELIS, however, showed that in its pool of hypercholesterolemic subjects, 80%...
### TABLE 3. Studies of Dietary Interventions and Cardiovascular Outcomes

<table>
<thead>
<tr>
<th>Type of Diet</th>
<th>Study/Author</th>
<th>Type of Study</th>
<th>Patients</th>
<th>Duration</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glycemic load–based diet</td>
<td>Nurses’ Health Study13</td>
<td>Prospective cohort</td>
<td>75,521</td>
<td>10 y</td>
<td>GL correlated directly with risk of coronary events.</td>
</tr>
<tr>
<td>Glycemic load–based diet</td>
<td>Italian Case-Control Study14</td>
<td>Case-control</td>
<td>881</td>
<td>4 y</td>
<td>Glucose did not correlate with risk of acute MI except in subgroup of patients &gt;60 y of age and those who were overweight/obese, in whom higher GL translated to higher odds ratios for MI.</td>
</tr>
<tr>
<td>Glycemic load–based diet</td>
<td>Zutphen Elderly Study15</td>
<td>Prospective cohort</td>
<td>646 Dutch men 64–68 y of age without diabetes or CAD</td>
<td>10 y</td>
<td>GL did not correlate with risk of coronary events.</td>
</tr>
<tr>
<td>Vegetarian diet</td>
<td>Health Food Shoppers Study16,17</td>
<td>Prospective cohort</td>
<td>10,736</td>
<td>18 y</td>
<td>Vegetarian diet resulted in a trend toward a lower ratio of mortality rate from ischemic heart disease to total death rate, 0.85 (95% CI, 0.71–1.01) in Health Food Shoppers Study; 0.88 (95% CI, 0.67–1.03) in Oxford Vegetarian Study; 0.75 (95% CI, 0.41–1.37) in EPIC-Oxford Study—but had no effect on all-cause mortality rate.</td>
</tr>
<tr>
<td>Mediterranean diet</td>
<td>Lyon Diet Heart Study18</td>
<td>Randomized trial</td>
<td>605 Post-MI patients</td>
<td>46 mo</td>
<td>Mediterranean diet (vs prudent Western-style diet) resulted in significant decrease in combined end point of cardiac death and nonfatal MI (1.2%/yr vs 2.6%/yr, P = 0.05)—and 18% decrease in rate of MI (P = NS).</td>
</tr>
<tr>
<td>Mediterranean diet</td>
<td>European Prospective Investigation into Cancer and Nutrition19</td>
<td>Prospective cohort</td>
<td>22,043</td>
<td>44 mo</td>
<td>Mediterranean diet was associated with 25% decrease in total mortality.</td>
</tr>
</tbody>
</table>

GL indicates glycemic load; CI, confidence interval; CVA, cerebrovascular accident; ICD, implantable cardioverter-defibrillator; VT, ventricular tachycardia; VF, ventricular fibrillation; LVEF, left ventricular ejection fraction; and RRR, relative risk reduction.
of whom did not have established CAD, high-dose EPA did not confer significant protection against sudden cardiac death or fatal MI. Similarly, the Study on Omega-3 Fatty Acid and Ventricular Arrhythmia (SOFA) had null results for the n-3 PUFAs (Table 3).92

Two studies have suggested that fish oil supplementation may actually be proarrhythmic in a subset of patients (Table 3).93,94 One of them was a double-blind trial of 200 patients who had implantable cardioverter-defibrillators placed for sustained ventricular tachycardia or ventricular fibrillation outside the setting of an acute MI and who were randomized to receive 1.8 g/d fish oil or “placebo” (olive oil). After 2 years of follow-up, among the 133 patients whose qualifying arrhythmia for entry to the trial was ventricular tachycardia, there were significantly more patients in the fish oil group who received implantable cardioverter-defibrillator therapy for ventricular tachycardia or ventricular fibrillation. This was not believed to reflect an antarrhythmic effect of olive oil in the “placebo” because there was no significant difference between the groups in red blood cell and plasma levels of the main constituents of olive oil (oleic acid and palmitic acid). This study therefore suggested that the previously demonstrated beneficial effects of fish oil on sudden cardiac death may not be due to the suppression of ventricular tachycardia or ventricular fibrillation. Alternatively, any antiarhythmic effect of fish oil, as demonstrated by the GISSI-Prevenzione trial, may be most profound in the setting of acute ischemia or recent MI. Outside this setting, when ventricular tachycardia occurs as a result of myocardial scar-based reentry, fish oil may actually increase the risk of ventricular tachycardia or ventricular fibrillation. These hypotheses only underscore the need for further research to better define the context in which fish oil could benefit patients with CAD.

There has been a suggestion that the eicosanoids derived from the n-3 PUFAs are opposed by those derived from the n-6 PUFAs, which have been shown to be prothrombotic and proaggregatory. This led to the notion that a critical dietary ratio of n-6 to n-3 PUFA exists that should not be exceeded if optimal cardiovascular health is desired.104 Unfortunately, there are insufficient studies to conclusively support the validity of this hypothesis.

**Mediterranean Diet**

In the Lyon Diet Heart Study, 605 post-MI patients were randomized to a Mediterranean diet or a prudent post-MI diet recommended by their attending physicians (Table 3).105 After 27 months of follow-up, the rates of the combined end point of cardiac death and nonfatal MI in the Mediterranean-diet group and the prudent-diet group were 1.32% and 5.55% per year, respectively. At 46 months, the patients on the Mediterranean diet continued to demonstrate this benefit, with a rate of cardiac death and nonfatal MI of 1.24% per year as opposed to 4.07% in patients on the prudent diet.95 Notably, several years after randomization, most of the patients instructed to follow the Mediterranean diet continued to adhere to this recommendation. A similar conclusion was provided by a population-based prospective study of >22 000 adults in Greece that demonstrated that through 44 months of follow-up, every 2-point increase in the score of adherence to the traditional Mediterranean diet corresponded to a 25% reduction in total mortality (Table 3).96 Works by Ram Singh such as the Indo-Mediterranean Diet Heart Study, proposed similar findings in the South Asian population. However, of late, serious collective concerns about the credibility of Singh’s data have been raised.106

The cardiovascular benefits afforded by the Mediterranean diet are easily appreciated when the benefits of its individual constituents are reviewed. Olive oil, a good source of MUFA s, contains phenolic compounds that may have antioxidant, antiinflammatory, and antithrombotic properties.107 Consumption of fruits and vegetables has likewise been shown to be inversely related to the risk of CAD. Enterolactone, a compound produced in the intestines by the bacterial fermentation of lignan precursors from plant foods, has been used as a marker of fruit and vegetable consumption. In the Kuopio Ischemic Heart Disease Risk Factor Study, which followed up 1889 middle-aged Finnish men for 12 years, serum enterolactone levels correlated inversely with the risk of death from CAD.108 Similarly, a pooled analysis of 10 prospective cohort studies on dietary fiber and CAD risk showed that every 10-g increase in fiber intake per day was associated with a 14% decrease in risk of all coronary events and a 27% decrease in risk of death from CAD.109 In light of these data, most professional dietary recommendations specify an intake of at least 25 to 30 g/d of whole-grain products, fruits, and vegetables.5,110 Frequent consumption of nuts, which are good sources of MUFA s, PUFAs, fiber, and flavonoids, has been shown to decrease cardiovascular disease risk in large studies.111-112 Most studies on alcohol have likewise found that moderate consumption reduces cardiovascular mortality. In a 9-year prospective study of 490 000 men and women, the rates of death from all cardiovascular diseases were 30% to 40% lower in men and women who reported at least 1 drink per day than in nondrinkers.113 This is believed to be due to the favorable effects of alcohol on serum HDL, apolipoprotein A-1, tissue-type plasminogen activator, and CRP levels; effects on platelet function; and the antioxidant activity of phenolic compounds and flavonoids in alcohol.114

**Concerns About Common Dietary Practices**

Long-term adherence can become a problem with some dietary fads that use severe restriction of certain food groups. In trials that investigated the effectiveness of low-carbohydrate diets in inducing weight loss, the attrition rates ranged between 24% and 39%.19-22 In most of these trials, comparable attrition rates were observed in subjects assigned to a low-fat diet. Furthermore, when a major change in the proportion of one macronutrient is imposed, compensatory changes in the proportions of other macronutrients will naturally occur. In the case of low-carbohydrate diets, there is a concern that excessive dietary protein intake can occur and potentially increase long-term risks for nephrolithiasis.115 There is also a concern for the ketogenic nature of low-carbohydrate diets, although no adverse consequences have been reported thus far from the mild ketosis that occurs in this setting.
When dietary fat intake is severely restricted, biochemical evidence of essential fatty acid deficiency can result. Some clinical consequences have been reported, including episodic somnolence, visual problems, and tachyarrhythmias, especially when fat intake remains <5% of total calories for several years. In addition, the promotion of severely fat-restricted diets has led many consumers today to resort to fat substitutes in commercially available low-fat or “fat-free” snacks instead of naturally occurring low-fat foods such as fruits, vegetables, and whole grains; the consequence often has been an increased consumption of refined carbohydrates.

The Environmental Protection Agency and Food and Drug Administration have issued advisories on how to appropriately limit fish consumption. These are based on concerns that environmental toxins such as mercury, polychlorinated biphenyls, and dioxins are bioconcentrated in the food chain in fresh waters and oceans, making fish a major source. Although suggestions have been made that long-term accumulation of these toxins may increase the risk of cancer, a recent meta-analysis did not show an increased risk of cancer with higher intake of n-3 PUFAs.

For soy proteins, the primary concerns relate to their potential for estrogenic and goitrogenic activities, the latter possibly being more relevant in the setting of iodine deficiency. Concerns about ingesting too much plant sterols and stanols have likewise been raised. Plant sterols, for example, might reduce the absorption of some fat-soluble vitamins such as beta-carotene, alpha-carotene, and vitamin E. Plant sterols also are potentially atherogenic, and several individuals who carry the recessive trait of sitosterolemia, in which mutations in the ABCG5 and ABCG8 genes cause an increased absorption and impaired biliary clearance of plant sterols, have been reported to develop premature CAD. Plant sterols and stanols, however, are virtually unabsorbable in most individuals. Therefore, the risk of sitosterolemia and its adverse consequences is minimal. In individuals with high cardiovascular risks, the benefits of plant sterols and stanols generally outweigh the potential for harm. Nonetheless, many authorities remain hesitant to recommend therapeutic doses of these substances for the general public without additional safety data.

Although moderate alcohol consumption appears beneficial to the cardiovascular system, rates of death from injuries, violence, cirrhosis, and some cancers are higher among drinkers. As a result, the AHA and United States Dietary Guidelines Advisory Committee recommend no more than 1 drink (equivalent of ½ oz pure alcohol) per day for women and no more than 2 drinks per day for men.

Conclusions

Numerous studies have been conducted to help provide dietary recommendations for optimal cardiovascular health. The most compelling data appear to come from trials that tested diets rich in fruits, vegetables, MUFAs, and PUFAs, particularly the n-3 PUFAs. In addition, some degree of balance among various food groups appears to be a more sustainable behavioral practice than extreme restriction of a particular food group. Changes in dietary habits are generally cost-effective, and the means are widely available. Through heightened attention of health professionals and the public to current data on appropriate nutritional practices, better measures can be adopted to help reduce cardiovascular risk at a public health level.

Disclosures

None.

References


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**Key Words**: coronary disease □ diet □ heart failure □ hypercholesterolemia □ hypertension □ nutrition □ obesity
Impact of Dietary Patterns and Interventions on Cardiovascular Health
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In the article by Zarraga and Schwarz, “Impact of Dietary Patterns and Interventions on Cardiovascular Health,” which appeared in the August 29, 2006, issue (Circulation. 2006;114:961–973), two entries in Table 3 need to be corrected. On the first line, the results of the Nurses’ Health Study should read, “GL correlated directly with risk of coronary events;” as was stated in the text. In the third to the last study, by Raitt et al, the results should read, “1.8 g/d fish oil . . . Among patients with VT as qualifying rhythm for entry into trial, intervention resulted in significant increase in VT/VF occurrence.”

On page 967, the references for the first sentence, “Although appealing to advocates of the GI or glycemic load, this result did not find consistent support from observational studies (Table 3),” should be references 25, 78, and 79. These errors have been corrected in the current online version of the article. The authors regret the errors.

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