Published in final edited form as:

J Am Diet Assoc. 2008 February ; 108(2): 257–265. doi:10.1016/j.jada.2007.10.040.

Characteristics of the Diet Patterns Tested in the Optimal Macronutrient Intake Trial to Prevent Heart Disease (OmniHeart): Options for a Heart-Healthy Diet

Janis F. Swain, MS, RD, Phyllis B. McCarron, MS, RD, Eileen F. Hamilton, DTR, Frank M. Sacks, MD, and Lawrence J. Appel, MD

J. F. Swain is a bionutrition manager, General Clinical Research Center, Brigham and Women's Hospital, Boston, MA. P. B. McCarron is director of Metabolic Studies, Johns Hopkins ProHealth, and L. J. Appel is a professor of medicine, Welch Center for Prevention, Epidemiology, and Clinical Research, Johns Hopkins University, Baltimore, MD. E. F. Hamilton is retired; at the time of the study, she was a senior nutrition research assistant, Brigham and Women's Hospital, Boston, MA. F. M. Sacks is a professor of medicine, Cardiovascular Division and Channing Laboratory Department of Nutrition, Harvard School of Public Health, Boston, MA.

Abstract

Objective—To describe the nutrient and food composition of the diets tested in the Optimal Macronutrient Intake Trial to Prevent Heart Disease (OmniHeart).

Design—Two center, randomized, three-period crossover, controlled feeding trial that tested the effects of three healthful diet patterns on blood pressure, serum lipid levels, and estimated cardiovascular risk.

Subjects/setting—One hundred sixty-four participants with prehypertension and hypertension. During the 19 weeks of feeding, participants were required to consume only food prepared as part of the trial.

Intervention—The OmniHeart trial studied three diet patterns that differed in macronutrient composition: a carbohydrate-rich diet similar to the Dietary Approaches to Stop Hypertension diet (58% carbohydrate, 15% protein, and 27% fat), a higher protein diet that had 10% more protein and 10% less carbohydrate (48% carbohydrate, 25% protein, and 27% fat), and a higher unsaturated fat diet that had 10% more unsaturated fat and 10% less carbohydrate (48% carbohydrate, 15% protein, and 37% fat). Each diet contained 6% saturated fat and 100 to 200 mg cholesterol. Sodium was 2,300 mg at the 2,100 kcal energy level and was indexed across energy levels. Calcium, magnesium, and potassium were consistent with recommendations for the Dietary Approaches to Stop Hypertension diet and also indexed to energy levels. Each diet pattern met the major nutrient recommendations set by the *Dietary Guidelines for Americans 2005*. The 10% protein increase in the higher protein diet emphasized plant protein; however, meat and dairy food sources were also increased somewhat. Olive oil, canola oil, and olive oil spread were used liberally to achieve the unsaturated fat content of the higher unsaturated fat diet. The 10% reduction in carbohydrate in the higher protein diet and the higher unsaturated fat diet was achieved by replacing some fruits with vegetables, reducing sweets, and using smaller portions of grain products. All three diets reduced blood pressure, total and low-density lipoprotein cholesterol levels, and estimated coronary heart disease risk.

Conclusions—The OmniHeart diet patterns offer substantial flexibility in macronutrient intake that should make it easier to eat a heart-healthy diet and reduce cardiovascular disease risk.

Modification of diet can have powerful beneficial effects on blood pressure, blood lipid levels, and overall cardiovascular disease (CVD) risk. The Dietary Approaches to Stop Hypertension (DASH) trial (1) was an 11-week controlled feeding trial that studied three diet patterns. Results showed that a diet pattern, now referred to as the DASH diet, rich in fruits, vegetables, and low-fat dairy products; reduced in saturated fat and total fat; and modestly increased in protein substantially lowered blood pressure compared to a typical American diet. It also lowered plasma total and low-density lipoprotein (LDL) cholesterol levels without raising blood triglyceride concentrations, and lowered high-density lipoprotein cholesterol levels resulting in no change in the LDL: high-density lipoprotein cholesterol ratio (2,3). Subsequently, the DASH-Sodium trial (4) documented a direct, progressive relationship between sodium intake and blood pressure in both a typical American diet and the DASH diet.

Despite widespread agreement that reducing saturated fat lowers cardiovascular risk (2,3,5–7), the type of macronutrient (eg, carbohydrate, protein, or unsaturated fat) that should replace saturated fat has been controversial (8,9). In the absence of compelling evidence, the Institute of Medicine (5) and the third Report of the National Cholesterol Education Program Adult Treatment Panel III (6) recommend that a range of macronutrient profiles is acceptable.

The Optimal Macronutrient Intake Trial to Prevent Heart Disease (OmniHeart) tested the effects of partially substituting carbohydrate with protein and unsaturated fat on blood pressure, blood lipid levels, and estimated CVD risk (10,11). This trial tested the effects of three healthful diets (see Table 1) that were variations of the DASH diet pattern (12): a carbohydrate-rich diet (58% carbohydrate, 15% protein, and 27% fat) similar to the DASH diet, a higher protein diet that had 10% more protein and 10% less carbohydrate (48% carbohydrate, 25% protein, and 27% fat), and a higher unsaturated fat diet that had 10% more unsaturated fat and 10% less carbohydrate (48% carbohydrate, 15% protein, and 37% fat). Each diet contained 6% saturated fat and 100 to 200 mg cholesterol. Dietary intakes of sodium, potassium, calcium, magnesium and dietary fiber were similar in each diet and met the DASH trial targeted nutrient levels. These micronutrients were indexed to energy level (see Table 2). All diets met the major nutrient recommendations set by the *Dietary Guidelines for Americans 2005* (7).

All diets had favorable effects on CVD risk factors and estimated coronary heart disease risk, as shown in Table 3 (11). Compared to baseline, blood pressure, LDL cholesterol levels, and estimated coronary heart disease risk were lower on each diet and lowest on the higher protein diet. Blood triglyceride levels were reduced only in the higher protein and higher unsaturated fat diets.

The objective of this article is to describe within the context of the research study, the nutrient and food composition of the diets tested in the OmniHeart trial. Translation of these research diets for public health application will be presented in another article. This information will benefit food and nutrition professionals, researchers, and health educators to understand the foods that comprised the OmniHeart diets and for designing diets and eating plans that reduce CVD risk.

METHODS

OmniHeart was a 19-week randomized, three-period, crossover design, controlled feeding trial conducted at two clinical centers: the General Clinical Research Center at Brigham and

Women's Hospital, Boston, MA, and the Pro Health Clinical Research Unit of the Johns Hopkins Medical Institutions, Baltimore, MD (10).

Participants were recruited from the general public via direct mailings, newspaper advertisements, and individual referrals. Participants had to have prehypertension or stage 1 hypertension (ie, systolic blood pressure of 120 to 159 mm Hg and/or diastolic blood pressure of 80 to 99 mm Hg). No participants were taking blood pressure lowering medications. Of the 930 individuals screened, 214 started run-in and 191 were randomized to one of six diet sequences. One hundred sixty-one subjects were included in the final analysis (11). Institutional Review Boards at each center approved the trial protocol, and each participant provided written informed consent.

Feeding Protocol and Food Production

After completing two screening visits and acceptance into the study, subjects participated in a group orientation and a 6-day run-in period during which they followed the feeding protocol and consumed each intervention diet for 2 days. All food was prepared in the research kitchens of each institution, and similar procedures for food productions and distribution were maintained. Recipes were standardized, and food brands identified to be used throughout the study.

Participants were provided all their food throughout the study duration. They were instructed to eat only the food provided and not consume additional food. They came to the feeding site Monday through Friday to eat one meal onsite and remaining meals and weekend food were distributed to take home at that time. Body weight measurements using standard scales (Tanita BWB-800, Tokia, Japan or Health-o-meter 751 KLS, Bridgeview, IL) were taken daily Monday through Friday. According to study design, weight was maintained at $\pm 2\%$ of baseline by increasing or decreasing energy intake weekly. Food for a complete day corresponding to the subject's diet assignment was distributed for take home for unexpected occurrences that might prevent the participant from consuming his meal onsite.

Nutrient Targets and Diet Patterns

Three macronutrient diet patterns were tested (see Table 1). The carbohydrate-rich diet provided a total energy distribution of 58% carbohydrate, 15% protein, and 27% fat. Compared to carbohydrate-rich diet, the higher-protein diet was 10% higher in total protein than the carbohydrate-rich and higher unsaturated fat diets and emphasized protein from plant sources, which have been associated with lower blood pressure (13). To maintain a similar micronutrient profile in all OmniHeart diets, nonplant sources of protein were increased as well. The higher unsaturated fat diet was 10% higher in total fat than the carbohydrate-rich and higher protein diets with the additional fat coming primarily from monounsaturated fat.

Common to all diets was potassium, calcium, magnesium, and dietary fiber intake (see Table 2). These micro-nutrients were indexed to energy level and consistent with the DASH trial design (14). The sodium level was moderate (2,300 mg/day at 2,100 kcal), similar to the intermediate level in the DASH-Sodium trial (4).

Menu Development

For each diet, eight daily menus were developed and calculated using the nutrient software Food Processor (version 7.9, 2001, ESHA Research, Salem, OR). Missing food items or values were obtained from manufacturer's data or other published references. Based on food preparation issues and taste considerations, one menu was eliminated. The seven remaining menus (15) were then prepared at five energy levels: 1,600, 2,100, 2,600, 3,100, and 3,600

kcal. One to four unit foods (100 kcal each) in the form of cookies and proportional in nutrients to their respective diet pattern were used to meet energy needs between energy levels. Recipes, food preparation techniques, and brands were similar at each feeding site.

Food Group Servings

Food group servings were calculated for the three diet patterns using software from the United States Department of Agriculture (USDA, Agricultural Research Service, MyPyramid Equivalents Database for USDA Survey Food Codes, version 1) (16). Using this software, all foods for each diet, menu, and energy level were entered in gram weights and food group servings were calculated.

Food Group Classification

Food group classification was calculated for the 185 individual foods used in the OmniHeart trial following the description used in the DASH Study (12). Each food item in each menu was assigned to one of eight food groups according to the USDA food classification system (17). Each food group was then subdivided according to their USDA or botanical classification (18). The gram weight total for each food was entered into the corresponding classification. The total gram weight of all foods within that classification was then totaled and the percent contribution of each subgroup was calculated.

RESULTS

Pyramid Food Group Servings and Sources

Pyramid food group servings by energy level, shown in Table 4, increased across the five energy levels in the carbohydrate-rich, higher-protein, and higher unsaturated fat diets. Major differences in servings were in proportion to the diet's macronutrient and micronutrient profile. For example, at the 2,100-kcal level there were 5.3, 5, and 4.3 servings of grain in the carbohydrate-rich, higher protein, and higher unsaturated fat diets, respectively. Vegetables were lowest in the higher carbohydrate diet (4.4 servings) and highest in higher unsaturated fat diet (6.3 servings). The greatest number of fruit servings was in the carbohydrate-rich diet, reflecting the higher percentage of carbohydrate in that diet and the inherent higher carbohydrate content of fruit and fruit juices. Servings of dairy were slightly higher in the higher protein diet than the other two diets. The meat group is expressed as 1-oz meat equivalents. The carbohydrate-rich and higher unsaturated fat diets each had 5.1 (1 oz) servings at the 2,100-kcal level and the higher protein diet had nine (1 oz) servings reflecting the increased protein content.

Sugar and sweets, presented as teaspoons of sugar (1 tsp=5 g) were used minimally, although the carbohydrate-rich diet allowed for slightly more sugar-containing foods than in the higher protein and higher unsaturated fat diets.

Fats and oils were measured per teaspoon (1 tsp=5 g). For the 2,100-kcal diet, the carbohydrate-rich diet had 5.8 tsp, the higher protein diet had 3.3 tsp, and the higher unsaturated fat diet had 12.2 tsp, reflecting the increased monounsaturated fat in this diet.

The 10% protein increase in the higher protein diet emphasized plant protein (see Table 5). The higher protein diet had 72% (26 g) more plant protein than the carbohydrate-rich diet. Plant protein was increased by using larger portion sizes and by adding higher protein vegetables, beans, legumes, nuts, seeds, seitan (flavored wheat gluten) (19), and soy products. There was a 54% (16 g) increase in meat protein over the carbohydrate-rich diet, primarily via skinless poultry and egg white products. Protein from dairy increased 27% (5 g).

Sample Menus with Description

A 1-day sample menu for each diet in household measures and gram weights is shown in Table 6 at the 2,100-kcal energy level. Changes in overall nutrient composition were achieved by using differing portion sizes, the addition of vegetable protein and oils, and the substitution of potassium-rich vegetables for fruits. All menus emphasized whole-grain products and low-fat or fat-free dairy foods. A complete 7-day set of 2,100-kcal menus for all three OmniHeart diets given in gram weights and household measures is available from the corresponding author and on the OmniHeart Web site (15).

Menu Food Group and Subgroup Classifications

Food contributions in each of the three diets by food group and subgroup classifications for the 2,100-kcal menus are described in Table 7 and Table include the total average gram weight per day of each subgroup and its percent contribution by weight to the total subgroup.

In all three diets, breads (both white and wheat) and rolls contributed 44% to 55% of total grains. This was followed by pasta, rice, and hot breakfast cereals (18% to 21%) and ready-to-eat cereals (9% to 10%). The whole-grain subgroup (2% to 3%) included quinoa, millet, and bulgur. Seitan, a somewhat novel protein source and meat substitute, contributed 13% to the higher protein diet only.

Overall, fruits and fruit juices were used in greater amounts in the carbohydrate-rich diet; however, citrus fruits were used more frequently in the higher protein and higher unsaturated fat diets. Tropical fruits such as bananas, and temperate-climate fruits such as dried apricots, pears, apples, and peaches, were common in all three diets.

Within the vegetable group, tomatoes and tomato products accounted for between 34% and 49% of all vegetables in all diets, followed by green leafy vegetables (15% to 19%) such as spinach and lettuce, and cruciferous vegetables (10% to 13%) such as broccoli, cabbage, and cauliflower.

The major contributor to the meat, poultry, and fish category was skinless poultry, contributing 41% to 49% of overall consumption. Fish and shellfish comprised between 29% and 34%, all from tuna and scrod, and consumption of lean beef contributed between 11% and 19% to the three patterns. The use of egg-white products was more than five times greater in the higher protein than the carbohydrate-rich and higher unsaturated fat diets and helped keep cholesterol and saturated fat levels low while increasing protein.

Low-fat and fat-free milk comprised 70% to 77% of the dairy products group in all diets. Low-fat and fat-free yogurt contributed an additional 20% of dairy across all diets. Within the higher protein diet, low-fat cheese and pudding contributed additional protein.

Nuts, seeds, and legumes contributed to the higher protein content of the higher protein diet. Tree nuts and seeds contributed 30 g to 33 g per day to all three diets, whereas peanuts and peanut butter and legumes (including navy beans, chickpeas, hummus, and lentils) increased in the higher protein diet as a source of vegetable protein. Soy-based foods such as tofu, soy nuts, and soy breakfast sausage comprised 21% of this food group in the higher protein diet, but were used minimally otherwise.

Fats, oils, and salad dressings were all low in saturated fat and used in greater quantities in the higher unsaturated fat diet. Olive oil, rich in monounsaturated fat, and olive oil spread were most common. Other cooking oils used in lesser amounts included canola and safflower.

Sweets and snack foods are less nutrient-dense and were used sparingly, with similar gram weight contributions (27 g to 32 g) in all three diets.

DISCUSSION

Results from OmniHeart build on our previous feeding studies that documented the beneficial effects of the carbohydrate-rich DASH diet and reduced sodium intake on blood pressure, LDL cholesterol levels, and CVD risk (1,4). OmniHeart tested the effects of three healthful diets—a carbohydrate-rich diet similar to the DASH diet, a diet that had 10% more protein and 10% less carbohydrate than the carbohydrate-rich diet, and a diet that had 10% more unsaturated fat and 10% less carbohydrate than the carbohydrate-rich diet. In comparison to baseline, blood pressure, LDL cholesterol levels, and estimated coronary heart disease risk were 16% to 21% lower on each of the OmniHeart diets (11). Moderate replacement of carbohydrate with either protein or unsaturated fat further reduced CVD risk.

Although the OmniHeart diets have distinctive macro-nutrient features, they were designed to be similar in several key dimensions to the original DASH diet recommended for prevention and treatment of hypertension. The DASH diet is also the benchmark diet in the 2005 Dietary Guidelines (7) and is highlighted in the American Heart Association's Diet and Lifestyle Recommendations Revision 2006 (20). For example, each of the OmniHeart diets emphasizes fruits, vegetables, and low-fat dairy products; includes whole grains, poultry, fish, and nuts; and is reduced in red meat, sweets, and sugar-containing beverages. Each of the OmniHeart diets is rich in potassium, magnesium, calcium, and fiber and reduced in sodium and saturated fat.

The OmniHeart diets are best viewed as macronutrient variations of the DASH diet pattern. The carbohydrate-rich diet (58% carbohydrate, 15% protein, and 27% fat) is nearly identical to the original DASH diet (1) with slight variation in carbohydrate and protein intake making the protein content of the carbohydrate-rich diet similar to average US population intake (21). For those who prefer a diet rich in protein, the higher protein diet (48% carbohydrate, 25% protein, and 27% fat) provides a healthful alternative to certain popular diets that commonly emphasize red meats and other foods high in saturated fat or cholesterol. The level of protein in the higher protein (25% of energy) diet is considerably higher than the average American intake of 15% and also higher than most vegan diets that typically contain 10% to 12% protein (22). The higher unsaturated fat diet comes closest to a Mediterranean-style diet (23), which is characteristically higher in fat, especially monounsaturated fat, and rich in fruits and vegetables. Compared to the carbohydrate-rich and higher protein diets, the higher unsaturated fat diet had increased monounsaturated fat (8% of energy), poly-unsaturated fat (2% of energy), and reduced carbohydrate (10% energy) through the use of olive oil, canola oil, and other monounsaturated fats.

Potassium, calcium, and magnesium were held constant in all three diets. The reduction in carbohydrate from certain fruits and juices (bananas, apricots, oranges, and orange juice), breads, and grain-based snacks made achieving these micronutrient goals more complex in the higher protein and higher unsaturated fat diets. Increasing portion sizes and types of nutrient-dense yet lower carbohydrate vegetables, such as tomatoes (including tomato and vegetable juice) and broccoli provided additional micronutrients, especially potassium. The primary sources of calcium were reduced-fat dairy products. Calcium-fortified orange juice, now commonly available, was used occasionally to meet calcium targets. Meat, nuts, legumes, and whole grains, all rich in magnesium, were also incorporated into the diets.

Each diet provided 2,300 mg/day sodium at the 2,100 kcal energy level, the upper limit recommended by the American Heart Association (20), the 2005 Dietary Guidelines (7), and

the Joint National Committee for the Prevention and Treatment of High Blood Pressure guidelines (24). The level was easily achieved using readily available foods and avoiding highly processed foods. Vegetables were typically fresh or frozen and salted snack foods were avoided.

Dietary fiber content was consistent across diets. The 10% increase in protein in the higher protein diet emphasized plant sources, including legumes, whole grains, nuts, and soy products, all typically high in fiber. Therefore, to keep the higher protein diet within the study fiber ranges, more refined breads and cereals were sometimes used. Conversely, fiber-rich crude wheat bran was used to increase the fiber content of the higher unsaturated fat diet because carbohydrate, a frequent source of dietary fiber, was reduced 10%. These manipulations were made for research purposes (ie, to achieve similar levels of fiber and micronutrients in each dietary pattern). For practical applications, in which fiber-rich foods were used, the higher protein and higher unsaturated fat diets would not necessarily be reduced in fiber and in fact might have increased fiber and micronutrients, depending on the types of vegetables and grains consumed (25).

To avoid the higher protein diet being interpreted as a soy-based intervention and its results reflecting effects of soy nutrients, we used few soy products. Interestingly, a recent quantitative review (26) concluded that soy proteins and isoflavones do not substantially affect blood lipid levels or blood pressure. In a real-life application, using more soy products to increase vegetable protein could increase variety and acceptability of the higher protein diet.

It is important to emphasize that OmniHeart, similar to the DASH and DASH-Sodium trials, was a controlled feeding study. By maximizing adherence, the trial provides a powerful means to accurately estimate dietary effects. Rigorously conducted feeding studies often guide policy makers on what individuals should eat. However, these types of studies provide limited information on adherence to the diets in free-living individuals. Behavior intervention studies are a logical next step to understand adherence and its determinants in persons selecting their own food.

CONCLUSIONS

Results from OmniHeart, a controlled feeding study, support the concept that individuals have several options for consuming a heart-healthy diet that can reduce overall cardiovascular risk. The OmniHeart carbohydrate-rich diet is similar to the well-recognized DASH diet, the higher protein diet provides a healthful alternative for those who wish to consume additional protein, and the higher unsaturated fat diet is similar to a Mediterranean-style diet. Although the OmniHeart diets have distinct features in their macro-nutrient profiles, each was designed to follow many of the principles of the original DASH diet, which likely accounts for a portion of the impressive CVD risk factor reduction from baseline in all three diets. Furthermore, partial substitution of carbohydrate with protein and unsaturated fat likely led to further improvement in CVD risk factors. Given the variety of eating patterns in the US population, the OmniHeart diet patterns offer substantial flexibility in macronutrient intake that should make it easier to eat a heart-healthy diet and reduce CVD risk. Additional studies should explore adherence to the diets in free-living persons.

Acknowledgments

This work was supported by the National Institutes of Health, National Heart, Lung, and Blood Institute grant no. R01 HL 67098 and National Institutes of Health General Clinical Research Centers Program grant no. M01 RR02635.

The authors thank Eva Obarzanek, PhD, MPH, RD, NHLBI Branch Officer for the OmniHeart Trial; Karen Yee, MS, RD; Karen White, MS, RD; Scott McCarthy, RD; David Stebbins; and the staff of the metabolic kitchens at the Brigham and Women's Hospital and Johns Hopkins ProHealth.

References

1. Appel LJ, Moore TJ, Obarzanek E, Vollmer WM, Svetkey LP, Sacks FM, Bray GA, Vogt TM, Cutler JA, Windhauser MM, Lin P, Karanja N. A clinical trial of the effects of dietary patterns on blood pressure. DASH Collaborative Research Group. *N Engl J Med*. 1997; 336:1117–1124. [PubMed: 9099655]
2. Obarzanek E, Sacks FM, Vollmer WM, Bray GA, Miller ER 3rd, Lin PH, Karanja NM, Most-Windhauser MM, Moore TJ, Swain JF, Bales CW, Proschan MA. for the DASH Collaborative Research Group. Effects on blood lipids of a blood pressure-lowering diet: The Dietary Approaches to Stop Hypertension (DASH) Trial. *Am J Clin Nutr*. 2001; 74:80–89. [PubMed: 11451721]
3. Harsha DW, Sacks FM, Obarzanek E, Svetkey LP, Lin PH, Bray GA, Aickin M, Conlin PR, Miller ER 3rd, Appel LJ. Effect of dietary sodium intake on blood lipids: Results from the DASH-sodium trial. *Hypertension*. 2004; 43:393–398. [PubMed: 14707154]
4. Sacks FM, Svetkey LP, Vollmer WM, Appel LJ, Bray GA, Harsha D, Obarzanek E, Conlin PR, Miller ER 3rd, Simons-Morton DG, Karanja N, Lin P. for the DASH-Sodium Collaborative Research Group. Effects on blood pressure of reduced dietary sodium the Dietary Approaches to Stop Hypertension (DASH) diet. *DASH-Sodium Collaborative Research Group. N Engl J Med*. 2001; 344:3–10. [PubMed: 11136953]
5. Institute of Medicine, Food and Nutrition Board. Dietary Reference Intakes For Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids. Washington, DC: The National Academies Press; 2002.
6. Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). Bethesda, MD: National Heart, Lung, and Blood Institute; 2002. NIH Publication No. 02–5215
7. Nutrition and Your Health: Dietary Guidelines for Americans. 6th ed.. Washington, DC: US Government Printing Office; 2005. Home and Garden Bulletin No. 232
8. Conner WE, Conner SL. Should a low-fat, high-carbohydrate diet be recommended for everyone? The case for a low-fat, high carbohydrate diet. *N Engl J Med*. 1997; 337:562–563. [PubMed: 9262503]
9. Katan MB, Grundy SM, Willett WC. Should a low-fat, high carbohydrate diet be recommended for everyone? Beyond low-fat diets. *N Engl J Med*. 1997; 337(8):563–566. [PubMed: 9262504]
10. Carey VJ, Bishop L, Charleston J, Conlin P, Erlinger T, Laranjo N, McCarron P, Miller E, Rosner B, Swain J, Sacks FM, Appel LJ. Rationale and design of the Optimal Macro-Nutrient Intake Heart Trial to Prevent Heart Disease (OMNIHeart). *Clin Trials*. 2005; 2:529–537. [PubMed: 16422313]
11. Appel LJ, Sacks FM, Carey VJ, Obarzanek E, Swain JF, Miller ER 3rd, Conlin PR, Erlinger TP, Rosner BA, Laranjo NM, Charleston J, McCarron P, Bishop LM. for the OmniHeart Collaborative Research Group. Effects of protein, monounsaturated fat, and carbohydrate intake on blood pressure and serum lipids: Results of the OmniHeart randomized trial. *JAMA*. 2005; 294:2455–2464. [PubMed: 16287956]
12. Karanja NM, Obarzanek E, Lin P, McCullough ML, Phillips KM, Swain JF, Champagne CM, Hoben KP. for the DASH Collaborative Research Group. Descriptive characteristics of the dietary patterns used in the Dietary Approaches to Stop Hypertension trial. *J Am Diet Assoc*. 1999; 99 suppl:S19–S27. [PubMed: 10450290]
13. Elliot P, Stamler J, Dyer AR, Appel L, Dennis B, Kesteloot H, Ueshima H, Okayama A, Chan Q, Garside DB, Zhou B. for the INTERMAP Cooperative Research Group. Association between protein intake and blood pressure: The INTERMAP study. *Arch Int Med*. 2006; 166:79–87. [PubMed: 16401814]
14. Phillips KM, Stewart KK, Karanja NM, Windhauser MM, Champagne CM, Swain JF, Plin PH, Evans MA. for the DASH Collaborative Research Group. Validation of diet composition for the

- Dietary Approaches to Stop Hypertension trial. *J Am Diet Assoc.* 1999; 99 suppl:S60–S68. [PubMed: 10450296]
15. [Accessed November 28, 2006] OmniHeart menus: carbohydrate, protein, unsaturated fat. <http://www.OmniHeart.org>
 16. US Department of Agriculture, Agricultural Research Service Community Nutrition Research Group. [Accessed August 22, 2005] Pyramid Servings Database of USDA Survey Food Codes Version 1.0. 2000. http://www.ars.usda.gov/Services/docs.htm?docid=8503&pf=1&cg_id=0.
 17. US Department of Agriculture, Agricultural Research Service. *Data Tables: Results from USDA's 1995 Continuing Survey of Food Intakes by Individuals and 1995 Diet and Health Knowledge Survey* [book on CD-ROM]. Riverdale, MD: Continuing Survey of Food Intakes by Individuals/ Diet and Health Knowledge Survey; 1996.
 18. Huxley, A., editor. *The New Royal Horticultural Society Dictionary of Gardening*. New York, NY: Stockton; 1992.
 19. Nussinow, J. [Accessed March 5, 2007] Seitan—The vegetarian wheat meat. <http://www.vrg.org/recipes/vjseitan.htm>
 20. Lichtenstein AH, Appel LJ, Brands M, Carnethon M, Daniels S, Franch HA, Franklin B, Kris-Etherton P, Harris WS, Howard B, Karanja N, Lefevre M, Rudel L, Sacks F, Van Horn L, Winston M, Wylie-Rosett J. Diet and lifestyle recommendations revision 2006: A scientific statement from the American Heart Association Nutrition Committee. *Circulation.* 2006; 114:82–96. [PubMed: 16785338]
 21. Wight, JD.; Wang, CY.; Kennedy-Stephenson, J.; Ervin, RB. [Accessed November 13, 2007] Dietary intake of 10 key nutrients for public health, United States: 1999–2000. <http://www.cdc.gov/nchs/data/ad/ad334.pdf>
 22. Messina, VK.; Mangels, R.; Messina, M. *The Dietitian's Guide to Vegetarian Diets*. 2nd ed.. Sudbury, MA: Jones and Bartlett; 2004. Protein; p. 69
 23. Ferrara LA, Raimond AS, d'Epescopo L, Guida L, Russo AD, Maratta T. Olive oil and reduced need for antihypertensive medications. *Arch Intern Med.* 2000; 160:837–842. [PubMed: 10737284]
 24. The Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure. Washington, DC: US Department of Health and Human Services, National Institutes of Health, National Heart, Lung, and Blood Institute; 2003. NIH Publication No. 03–5233
 25. McManus K, Antinoro L, Sacks F. A randomized controlled trial of a moderate fat, low-energy diet compared with a low-fat, low-energy diet for weight loss in overweight adults. *Int J Obes.* 2001; 25:1503–1511.
 26. Sacks FM, Lichtenstein A, Van Horn L, Harris W, Kris-Etherton P, Winston M. Soy protein, isoflavones, and cardiovascular health: An American Heart Association science advisory for professionals from the Nutrition Committee. *Circulation.* 2006; 113:1034–1044. [PubMed: 16418439]

Table 1

The Optimal Macronutrient Intake Trial to Prevent Heart Disease (OmniHeart) macronutrient targets by diet

Macronutrient	Diet			Tolerance ^d (%)
	CARB ^a	PROT ^b	UNSAT ^c	
Total fat (%)	27	27	37	1
Saturated (%)	6	6	6	1
Monounsaturated (%)	13	13	21	1
Polyunsaturated (%)	8	8	10	1
Carbohydrate (%)	58	48	48	1
Protein (%)	15	25	15	1
Cholesterol (mg)	150	150	150	50

^aCARB=carbohydrate-rich diet.^bPROT=higher protein diet.^cUNSAT=higher unsaturated fat diet.^dAcceptable variation for each day's menu was the range defined by the nutrient target $\pm$ tolerance.

The Optimal Macronutrient Intake Trial to Prevent Heart Disease (OmniHeart) micronutrient targets for CARB^a, PROT^b, and UNSAT^c diets by energy level

Table 2

Micronutrient ^d	CARB, PROT, and UNSAT Diets					Tolerance ^e (%)
	Energy Level (kcal)					
	1,600	2,100	2,600	3,100	3,600	
Potassium (mg)	4,140	4,673	5,207	5,740	6,273	5
Calcium (mg)	1,040	1,240	1,440	1,640	1,840	5
Magnesium (mg)	430	497	563	630	697	10
Sodium (mg)	1,840	2,300	2,760	3,220	3,680	5
Dietary fiber (g)	26	30	36	41	46	15

^a CARB=carbohydrate-rich diet: 58% carbohydrate, 15% protein, and 27% fat.

^b PROT=higher protein diet: 48% carbohydrate, 25% protein, and 27% fat.

^c UNSAT=higher unsaturated fat diet: 58% carbohydrate, 15% protein, and 37% fat.

^d Nutrient targets were similar across all energy levels to the Dietary Approaches to Stop Hypertension (DASH) trial (13) and DASH-Sodium trial (4) intermediate sodium target range.

^e Acceptable variation for each day's menu was the range defined by the nutrient target±tolerance.

The Optimal Macronutrient Intake Trial to Prevent Heart Disease (OmniHeart) risk factor measures and mean changes from baseline (11) by diet pattern^a

Table 3

Clinical measure/risk	n	Baseline <i>mean±SD^e</i>	CARB ^b	PROT ^c	UNSAT ^d
<i>← mean change from baseline±SD→</i>					
Systolic Blood Pressure (mm Hg)					
All	164	131.2±9.4	-8.2±-9.6 to -6.8	-9.5±-10.9 to -8.2	-9.3±-10.6 to -8.0
Hypertension, stage 1 ^f	32	146.5±5.7	-12.9±-16.6 to -9.2	-16.1±-19.7 to -12.5	-15.8±-19.4 to -12.3
LDL^g cholesterol (mg/dL)^h					
All	161	129.2±32.4	-11.6±-14.6 to -8.6	-14.2±-17.5 to -10.9	-13.1±-16.4 to -9.8
≥130 (mg/dL) ^h	32	156.7±21.0	-19.8±-24.2 to -15.5	-23.6±-28.5 to -18.8	-21.9±-26.9 to -16.8
HDLⁱ cholesterol (mg/dL)^h	164	50.0±16.1	-1.4±-2.5 to -0.3	-2.6±-3.6 to -1.6	-0.3±-1.3 to 0.7
Triglyceride (mg/dL)^j	164	101.5±75 to 159	0.1±-8.6 to 8.8	-16.4±-25.5 to -7.3	-9.3±-17.5 to -1.2
Estimated 10-y coronary heart disease risk^k (%)		5.1	4.3	4.0	4.1

^a Adapted with permission from JAMA 2005;294:2456 (reference 11). Copyright © 2005, American Medical Association. All rights reserved.

^b CARB=carbohydrate diet: 58% carbohydrate, 15% protein, and 27% fat.

^c PROT=protein diet: 48% carbohydrate, 25% protein, and 27% fat.

^d UNSAT=unsaturated fat diet: 58% carbohydrate, 15% protein, and 37% fat.

^e SD=standard deviation.

^f Stage 1 hypertension is defined as systolic blood pressure 140 to 159 mm Hg.

^g LDL=low-density lipoprotein.

^h To convert mg/dL cholesterol to mmol/L, multiply mg/dL by 0.0259. To convert mmol/L cholesterol to mg/dL, multiply mmol/L by 38.7. Cholesterol of 193 mg/dL=5.00 mmol/L.

ⁱ HDL=high-density lipoprotein.

^j To convert mg/dL triglyceride to mmol/L, multiply mg/dL by 0.0113. To convert mmol/L triglyceride to mg/dL, multiply mmol/L by 88.6. Triglyceride of 159 mg/dL=1.80 mmol/L.

^k Framingham risk equation from: Wilson PW, D'Agostino RB, Levy D, BelangerAM, Silbershatz H, Kannel WB. Prediction of coronary heart disease using risk factor categories. *Circulation*. 1998;97:1837-1847.

Food Group^a (2000 Food Guide Pyramid) and subgroup servings by energy level and diet: Optimal Macronutrient Intake Trial to Prevent Heart Disease (OmniHeart) diets

Food group	Energy Level (kcal)														
	1,600			2,100			2,600			3,100			3,600		
	CARB ^b	PROT ^c	UNSAT ^d	CARB	PROT	UNSAT	CARB	PROT	UNSAT	CARB	PROT	UNSAT	CARB	PROT	UNSAT
Grains (servings)	4.0	3.8	3.2	5.3	5.0	4.3	6.0	6.7	5.4	7.2	8.0	6.6	8.7	9.1	8.6
Vegetables (servings)	4.4	5.0	6.8	4.4	5.4	6.3	4.8	6.3	7.0	5.5	7.1	7.2	5.7	6.8	7.6
Fruit (servings)	5.7	3.1	3.2	6.6	3.8	4.8	7.6	4.1	5.8	8.4	4.8	5.9	9.0	5.4	6.9
Dairy ^e (servings)	1.6	2.0	1.6	2.1	2.5	1.9	2.5	2.7	2.2	2.9	3.1	2.5	3.0	3.4	2.9
Meat equivalents total ^f (1 oz)	3.7	7.6	4.1	5.1	9.1	5.1	6.2	11.7	7.1	7.9	13.6	8.1	11.9	14.5	11.6
Legumes	0.3	0.7	0.3	0.5	0.9	0.4	0.6	0.8	0.5	0.7	0.9	0.5	0.8	0.9	2.5
Egg product substitute	0.0	0.8	0.1	0.2	1.1	0.1	0.1	1.4	0.2	0.1	1.8	0.2	0.1	2.1	0.2
Meat	0.5	1.3	0.7	0.9	1.1	1.0	1.0	1.4	1.3	1.6	1.6	1.7	1.8	1.7	2.4
Poultry	1.3	2.0	1.4	1.6	2.6	1.8	2.0	3.8	2.3	2.6	3.9	2.8	3.0	4.4	3.1
Fish	1.0	1.2	1.0	1.1	1.3	1.0	1.5	1.4	1.6	1.6	1.9	1.6	1.8	1.6	1.8
Soy and meat analog	0.0	0.8	0.0	0.0	0.9	0.0	0.0	1.5	0.0	0.1	1.8	0.0	0.1	1.8	0.0
Nuts and seeds	0.6	0.8	0.6	0.8	1.2	0.8	1.0	1.4	1.2	1.2	1.7	1.3	1.3	2.0	1.6
Desserts and sweets (tsp sugar) ^g	2.8	0.7	0.2	4.6	2.5	1.7	7.2	3.1	3.1	11.0	4.6	4.9	11.8	5.5	7.6
Fats/oil (tsp) ^h	4.5	2.7	9.9	5.8	3.0	12.2	7.1	3.8	15.0	8.0	4.4	16.8	9.2	4.9	18.6

7. Calculated using US Department of Agriculture (USDA), 2000 Pyramid Servings Database for USDA Survey Food Codes. ARS Community Nutrition. (USDA 2005 MyPyramid software not yet available).

^b CARB=carbohydrate diet: 58% carbohydrate, 15% protein, and 27% fat.

^c PROT=protein diet: 48% carbohydrate, 25% protein, and 27% fat.^dUNSAT=unsaturated fat diet: 58% carbohydrate, 15% protein, and 37% fat.^e Predominately low-fat dairy.

^fMeat equivalents=1 oz equivalents.

^g Desserts and Sweets (5 g=1 tsp sugar)=Sugar content of candy, cookies, cake, pudding, jelly, gelatin.

^h Converted from fat grams: 5 g = 1 tsp oil or margarine.

Table 5

Protein sources, grams protein, and percent contribution for each diet pattern in the Optimal Macronutrient Intake Trial to Prevent Heart Disease (OmniHeart) (2,100 kcal energy level)

Food category	CARB ^a		PROT ^b		UNSAT ^c	
	Protein (g)	Contribution (%) ^d	Protein (g)	Contribution (%)	Protein (g)	Contribution (%)
Plant (total)	35.9	42.3	61.7	46.8	34.3	40.9
Meat (total)	29.6	34.9	45.7	34.6	32	38.2
Beef, pork	9.5	11.2	8.9	6.8	8.3	9.9
Poultry	11.5	13.6	22.5	17	15.5	18.5
Fish	7.5	8.8	8.5	6.5	7.4	8.8
Egg products	1.1	1.3	5.8	4.4	0.8	0.9
Dairy (total)	19.4	22.8	24.6	18.6	17.5	20.9

^aCARB=carbohydrate diet: 58% carbohydrate, 15% protein, and 27% fat.

^bPROT=protein diet: 48% carbohydrate, 25% protein, and 27% fat.

^cUNSAT=unsaturated fat diet: 58% carbohydrate, 15% protein, and 37% fat.

^dPercent contribution calculated as the percent of protein gram weight by food category to the total diet protein gram weight..

Table 6

One-day sample menu^a (2,100 kcal) by household measure and gram weight: The Optimal Macronutrient Intake Trial to Prevent Heart Disease (OmniHeart)

Meal	CARB ^b			PROT ^c			UNSAT ^d		
	Household measure ^e	Gram weight	Food item	Household measure	Gram weight	Food item	Household measure	Gram weight	Food item
Breakfast	1 c	240	Grapefruit juice	¾ c	163	Tomato juice	¾ c	160	Orange juice
	1 oz	32	Bran squares cereal	½ c	100	Egg substitute with	1 slice	30	Bread
	1 ¾ med	293	Banana (with peel)	2T	15	low-fat cheese	2 tsp	10	Olive-oil margarine
	1 c	236	Fat-free milk	1 tsp	5	Olive-oil margarine	2 tsp	12	Diet jelly
				½ c	84	Bulgar wheat cereal with soy flakes (cooked)	1 small	130	Banana (with peel)
				1 tsp	6	Sugar	1 c	236	Low-fat milk
Lunch				1 oz	28	Raisins			
				1 c	236	Fat-free milk			
			Chicken salad sandwich:			Vegetarian Burger:			Omni chili:
	2 slices	56	Whole-wheat bread	1 med	46	Hamburger roll	½ c	119	Omni chili with tofu
	2 ½ oz	80	Chicken breast	3 oz	100	Vegetarian patty	2 tsp	8	Canola oil
	2 ½ tsp	12	Mayonnaise	2 ½ tsp	12	Barbeque sauce	½ oz	13	Low-fat cheese
	¼ c	20	Lettuce	½ c	30	Iceburg lettuce	12 medium	45	Black olives
	2 tsp	10	Olive oil	3 slice	50	Tomato	1 oz	30	Tortilla chips
	1 oz	28	Almonds	½ c	60	Broccoli salad w/apricots, sunflower seeds, celery	½ c	94	Bulgar wheat salad with almonds, tomato, raisins
	1 oz	28	Apricots (dried)						
				1 oz	28	Potato chips, unsalted	1 ½ tsp	7	Olive oil
				½ c	99	Chocolate pudding (made with fat-free milk)	1 oz	27	Peanuts
						Black bean nacho:	½ c	113	Pears (canned in juice)
							6 oz	185	Cod fillet with
Dinner	1 ¾ c	254	Penne bean pasta ^f						
	2 tsp	10	Olive oil	½ c	74	Black beans	1T	15	Olive oil
	1 oz	27	Beef meatballs	1 oz	39	Seitan (<i>wheat protein</i>)	1T	7	Bread crumbs
	1T	12	Parmesan cheese	½ c	74	Tomato	1 tsp	3	Lemon juice
	1 ½ c	56	Romaine lettuce	2 tsp	8	Olive oil	¾ c	150	Spinach, (steamed)

Meal	CARB ^b			PROT ^c			UNSAT ^d		
	Household measure ^e	Gram weight	Food item	Household measure	Gram weight	Food item	Household measure	Gram weight	Food item
	½ c	68	Cherry tomatoes	3 oz	92	Skinless chicken breast	1 ½ tsp	7	Safflower oil
	2 ½ tsp	12	Fat-free salad dressing	1 oz	24	Tortilla chips	¾ c	150	Carrots, (cooked)
	1 ½ tsp	6	Safflower oil	½ c	45	Three-grain pilaf	4 tsp	20	Olive oil margarine
	1 c	165	Grapes	1 med	159	Orange	1 smal	38	Dinner roll
	½ oz	14	Peppermint patty	1 c	236	Fat-free milk	½ oz	14	Peppermint patty
Snack	¾ c	170	Low-fat yogurt	¼ c	58	Fat-free cottage cheese	½ c	125	Fat-free yogurt
	1 med	138	Apple	½ c	113	Mandarin oranges (in juice)	1 medium	182	Banana (with peel)
				1 oz	28	Almonds			

^aRepresents a 1-day menu for each of the OmniHeart diets as used in the trial to meet all nutrient targets.

^bCARB=carbohydrate diet: 58% carbohydrate, 15% protein, and 27% fat.

^cPROT=protein diet: 48% carbohydrate, 25% protein, and 27% fat.

^dUNSAT=unsaturated fat diet: 58% carbohydrate, 15% protein, and 37% fat.

^eHousehold measures rounded from gram weight.

^fRecipe: Cooked penne pasta, tomato sauce, navy beans, spinach, olive oil, onion, garlic powder, chili powder, and sage.

Table 7

Food group and subgroup classification, average daily gram weight, and percent total and subgroup contribution for 2,100-kcal energy level of each diet pattern in the Optimal Macronutrient Intake Trial to Prevent Heart Disease (OmniHeart)

Food group and subgroup	CARB ^a		PROT ^b		UNSAT ^c	
	g/d ^d	Contribution (%) ^e	g/d	Contribution (%) ^e	g/d	Contribution (%) ^e
Grains (total)	168	100	172	100	131	100
Yeast breads and rolls	88	52	75	44	73	55
Baked goods (cakes, cookies, pastries)	8	5	10	6	8	6
Grain-based snacks (crackers, popcorn, pretzels)	14	8	8	4	6	5
Ready-to-eat breakfast cereals	16	9	17	10	13	10
Pasta, rice and hot breakfast cereals	35	21	33	19	24	18
Whole grains (bulgur, millet, quinoa, wheat bran)	4	3	4	2	4	3
Gravy (fat free)	3	2	3	2	3	3
Seitan (wheat gluten)	0	0	22	13	0	0
Fruits and fruit juices (total)	713	100	429	100	528	100
Citrus fruits	39	5	72	17	62	12
Berries	4	1	0	0	0	0
Temperate climate fruits (pears, apples, peaches, apricots)	147	21	79	18	90	17
Melons	22	3	45	11	22	4
Tropical fruits (banana, pineapple)	153	21	94	22	127	24
Fruits in mixtures (fruit cocktail)	16	2	0	0	0	0
Juices (sweetened and unsweetened)	332	47	139	32	227	43
Vegetables (total)	362	100	428	100	535	100
Solanaceae, night shade family (tomato and tomato products)	176	49	145	34	230	43
Other solanaceae (peppers, potatoes)	6	2	12	3	6	1
Allium vegetables (onions, garlic, leeks)	5	1	14	3	5	1
Cruciferous vegetables (cabbage, broccoli, cauliflower)	36	10	58	13	61	11
Deep-yellow/orange vegetables (winter squash, sweet potatoes)	19	5	7	2	21	4
Green leafy vegetables (lettuce, spinach)	70	19	63	15	95	18
Umbelliferae (carrots, celery, parsley)	25	7	33	8	48	9
Leguminous vegetables (green beans, peas, lima beans)	14	4	23	5	14	3

Food group and subgroup	CARB ^a		PROT ^b		UNSAT ^c	
	g/d	Contribution (%) ^e	g/d	Contribution (%) ^e	g/d	Contribution (%) ^e
Cucurbitaceae or gourd vegetables (cucumbers, zucchini)	11	3	34	8	32	6
Other vegetables (corn)	0	0	14	3	7	1
Other (ripe olives)	0	0	0	0	16	3
Other (veggie patties)	0	0	25	6	0	0
Meat, poultry, and fish (total)	111	100	147	100	120	100
Beef	18	17	16	11	23	19
Pork	9	8	16	11	9	8
Poultry	46	41	73	49	50	42
Fish and shellfish	38	34	43	29	38	31
Egg and egg products (total)	10	100	55	100	7	100
Dairy products (total)	456	100	527	100	439	100
Milk (low-fat and fat free)	353	77	370	70	328	75
Yogurt (low-fat and fat-free)	91	20	89	17	92	21
Cheese (soft and hard)	12	3	40	7	5	1
Dairy desserts (puddings)	0	0	28	6	14	3
Nuts, seeds, and legumes (total)	92	100	166	100	68	100
Nuts and seeds (pecans, walnuts, almonds, cashews)	31	34	30	18	33	48
Legumes (navy beans, chick peas, hummus, lentils, lentil loaf)	52	56	85	51	28	41
Peanuts and peanut butter	3	3	16	10	4	6
Soy (tofu, soy nuts, breakfast sausage links)	6	7	35	21	3	5
Fats, oils, and salad dressings (total)	46	100	31	100	70	100
Table fats (margarine and spreads)	7	15	4	14	22	32
Salad dressings and mayonnaise	20	43	17	55	10	14
Cooking oils (other than olive oil)	11	25	2	7	13	18
Olive oil	8	17	8	24	25	36
Sweets and snack foods (total)	27	100	28	100	32	100
Sugars (plain sugar, jelly, syrup, gelatin desert)	10	35	18	64	23	73
Candy	9	35	2	7	2	6
Salty snacks (potato chips)	8	30	8	29	7	21

^aCARB=carbohydrate diet: 58% carbohydrate, 15% protein, and 27% fat

^bPROT=protein diet: 48% carbohydrate, 25% protein, and 27% fat

^cUNSAT=unsaturated fat diet: 58% carbohydrate, 15% protein, and 37% fat

^dThe average gram weight contribution of all foods within that subgroup from the 7-day menu cycle.

^eThe percent contribution by weight of the food subgroup to the total food group.