N U T R I T I O N
close UP

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Nutrition Close-Up is a quarterly publication of the American Egg Board, written and produced by the Egg Nutrition Center. *Nutrition Close-Up* presents up-to-date reviews, summaries and commentaries on the latest research on the role of diet in health promotion and disease prevention, including the contributions of eggs to a nutritious and healthful diet. Nutrition and health care professionals can receive a **free** subscription for the newsletter by contacting the Egg Nutrition Center.

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Celebrating 25 years of nutrition research and health education (1979-2004)

Protein Intake Promotes Satiety, Improves Body Weight and Composition

Recent research comparing the effectiveness of low-carbohydrate diets with that of traditional low-fat, high-carbohydrate diets has demonstrated what many see as a contradiction—that both appear equally effective in reducing body weight. This perceived ambiguity has left health professionals and practitioners wondering how these extreme dietary approaches can result in similar weight loss. While many clinical studies have been undertaken to examine high-protein/low-carbohydrate diets, none have clarified whether their positive effects come from cutting carbohydrates or increasing the proportion of calories from protein. In an effort to untangle the data surrounding the high-protein/low-carbohydrate debate, Weigle et al. conducted a clinical trial in which carbohydrate intake was held constant while energy from protein was proportionally increased.

Nineteen healthy adults were recruited to participate in this trial. None of the participants were pregnant or chronically ill. None reported drinking more than 2 alcoholic beverages/day or using tobacco, and none were in the habit of exercising regularly more than 30 minutes/day, 3 times/week. All were weight-stable and each had a body mass index (BMI) >30 kg/m^2. Since intention to lose weight would likely have influenced the results, participants were informed that this was not a weight-loss study; individuals who expressed a desire to lose weight as a result of participation in the trial were excluded.

Participants who met the selection criteria completed a 3-day food record and began a two-week "baseline" moderate-protein (MP) diet. The macronutrient distribution of this initial diet was 35% of total calories from fat, 50% from carbohydrate, and 15% from protein. All meals were prepared in the research kitchen and picked up by participants, who were asked to eat all foods provided. The diets were matched to participants' calorie needs to ensure maintenance of baseline body weight during this initial phase. Participants recorded all foods eaten and reported hunger and satiety levels daily using 100-mm visual analog scales to answer the following questions: "How hungry have you felt between meals today?" and "How full have you felt after eating meals today?"

On the last day of the initial two-week MP phase, participants reported to the research center. Blood was drawn at regular intervals through the day and night for assessment of serum ghrelin and leptin (the hormones that regulate hunger and satiety, respectively). Resting metabolic rate (RMR) was determined by indirect calorimetry.

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For the subsequent 2 weeks, participants followed an isocaloric HP diet consisting of 20% total calories from fat, 50% from carbohydrate, and 30% from protein. This diet phase was calorie-controlled, like the first, to ensure weight maintenance. Again, participants obtained all meals from the research kitchen and were expected to consume all foods provided. Each participant was weighed 2-3 times a week and hunger and satiety levels were recorded daily. On the last day of this diet phase, participants again reported to the research center for assessments of weight, serum leptin and ghrelin, and body composition [determined by dual-energy x-ray absorptiometry (DEXA)].

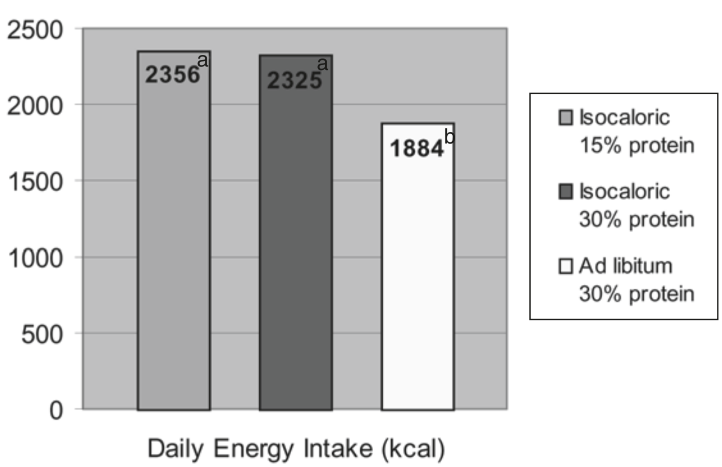
The final HP diet phase began immediately following the second visit to the research clinic. The macronutrient distribution was the same as that of the calorie controlled HP phase (20% fat, 50% carbohydrate, and 30% protein), but this diet phase was designed to be ad libitum. It provided 15% more calories than needed by each participant daily. The women were asked not to make any efforts to lose or gain weight and were encouraged to eat in response to hunger cues. For 12 weeks, participants were provided with sufficient food to cover their calorie requirements + 15%. Food choices were expanded somewhat to prevent changes in appetite due to boredom with the food selection. Participants recorded daily intake and appetite ratings as before. Uneaten food was returned at each visit to the research center during this final phase. At the end of the 12 weeks, participants again reported to the research center for a final assessment of hormone levels, RMR, and body composition.

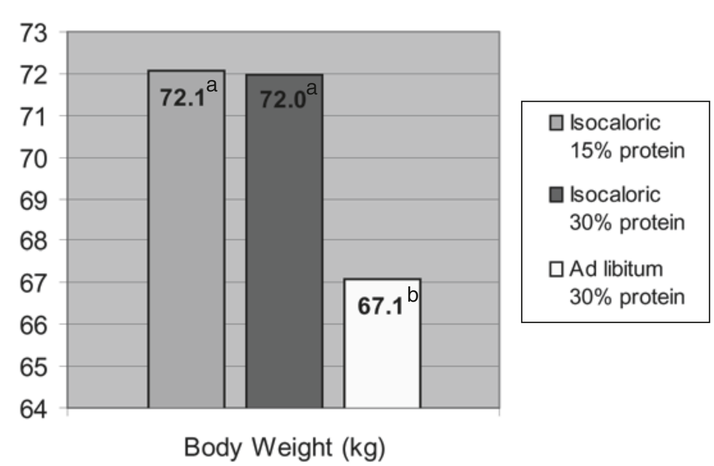
The authors compared fiber, calcium, and fat intake levels consumed during the HP and MP diet phases. Intake of dietary fiber was 11.8 g/1000 kcal for the MP diet and 10.2 g/1000 kcal for the HP diet. Calcium intake was 450 vs. 700 mg/1000 kcals for the MP vs. HP diet, respectively. The distribution of types of fat consumed also differed; 12.7% saturated, 11.5% monounsaturated, and 9.9% polyunsaturated for the MP diet, and 7.6% saturated, 7.4% monounsaturated, and 3.9% polyunsaturated for the HP diet.

Participants successfully maintained their baseline body weights over the first four weeks of the study, indicating that compliance with the prescribed isocaloric MP and HP diets was good. Average body weight for the participants steadily declined over the course of the final 12-week ad libitum phase, resulting in an average weight loss of 4.9±0.5 kg per participant. This corresponded with a spontaneous decrease in caloric intake of 494±74 kcals/day (from 2325±85 to 1884±101 kcals/day), which began with the initiation of the HP ad lib diet and was sustained throughout the 12-week phase. Body composition testing demonstrated that an average of 76% (3.7±0.4 kg) of the weight lost was from adipose tissue. (See figures below. Values with different superscripts are significantly different; $p<0.05$.) RMR did not differ significantly for any participant at any point during the study.

Plasma leptin values remained steady across the first and second diet phases. During the 12-week ad lib phase, however, leptin decreased significantly from baseline. This decline was largely accounted for by the significant reduction in fat mass observed during the ad lib phase.

Participants reported markedly decreased hunger scores and elevated satiety scores following the transition from the MP to the HP isocaloric diet. These scores returned to normal soon after the 12-week ad lib HP diet began. These observations do not necessarily correspond with rising and falling leptin and ghrelin levels over the course of the study. For example, ghrelin values were significantly higher following the ad libitum phase than at the end of the first or second phase. In addition, no significant change in leptin





(Values with differing superscripts are significantly different; p<0.05)

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was observed when participants began reporting increased satiety at the beginning of the HP ad libitum phase. The authors speculate that increased protein intake might enhance the satiating effect of circulating leptin.

With only 19 participants making up the research cohort, this study was small; however, its findings introduced worthwhile questions for future research and began to address persistent misgivings among healthcare professionals regarding the therapeutic value of such diets. Weigle et al. undertook this clinical trial to test the theory that high protein intake increases satiety and reduces spontaneous caloric intake within the context of a moderate-carbohydrate diet. The purpose of this study was not to compare very high-protein or very low-carbohydrate diets; rather, it was to compare diets of moderate and high protein content against a background of consistent carbohydrate intake.

This study provides valuable insight on the role of protein in the regulation of spontaneous caloric intake. It is preceded by a similar study (also by Weigle et al.) in which dietary protein was held constant while fat intake was reduced. While the authors acknowledge the possibility that the weight reduction observed in the current study was partially due to a decrease in dietary fat, they also cite observations from their own previous research demonstrating that a larger reduction in dietary fat coupled with an increase in carbohydrates (no change in protein) resulted in a smaller degree of weight loss (3.7±0.6 vs. 4.9±0.5 kg; P=0.13) than in the present study. Therefore, increasing the proportion of calories from protein appears more effective in promoting weight loss than decreasing calories from fat, alone.

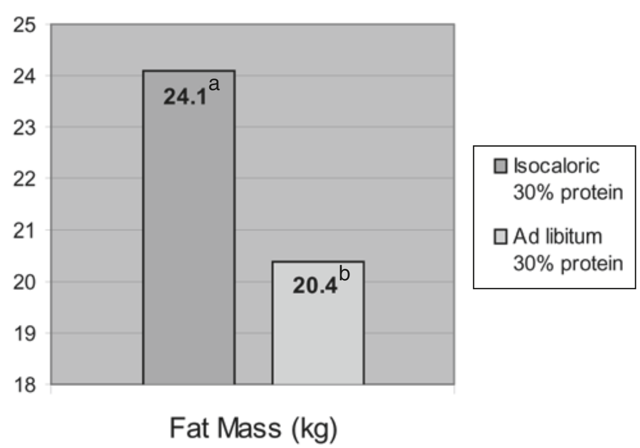
The authors conclude that the improvements in body weight and body composition observed in this study were largely due to increased satiety and a resultant decrease in caloric intake during the ad libitum phase. They further conclude that an increased proportion of calories from protein was likely responsible for these outcomes.

Weigle DS, Breen PA, Matthys CC, et al. A high-protein diet induces sustained reductions in appetite, ad libitum caloric intake, and body weight despite compensatory changes in diurnal plasma leptin and ghrelin concentrations. *Am J Clin Nutr* 2005;82:41-48.

Key messages

In this study, increasing protein intake while maintaining the proportion of calories from carbohydrate resulted in...

- higher satiety scores
- spontaneous decrease in total energy intake
- greater weight loss
- improved body composition



Comment

The "high"-protein diet employed by Weigle et al. in this study was, in reality, not exceptionally high at all. The experimental high-protein diet provided 30% of total calories from protein, a proportion well within the acceptable macronutrient distribution range (AMDR) set in 2002 by the Institutes of Medicine (IOM). According to the IOM, the acceptable range of protein intake within the context of a healthy diet is 15-35% of energy (AMDR for fat is 20-35% and for carbohydrate is 45-65%), meaning that the lower-protein diet (15% calories from protein) utilized in this study was actually on the low end of the AMDR for protein.

High-protein, Low-fat Diet Improves CVD Risk Factors in Women

Many of the highly-publicized criticisms leveled against high-protein diets stem from the fact that they are also stereotypically high in fat. One important concern among consumers and healthcare professionals is that dietary patterns characterized by high protein intake might negatively influence risk factors for cardiovascular disease (CVD). However, according to a recent study by Noakes et al., high-protein diets that are low in fat are at least as effective as low-fat, high-carbohydrate diets in decreasing weight and improving risk factors for CVD.

This research team recruited 100 overweight women (BMI 27-40 kg/m^2) between the ages of 20 and 65 years with no history of diabetes to participate in a clinical trial that would evaluate the relative effects of low-fat, high-protein and low-fat, high-carbohydrate diets on weight loss, CVD risk factors, bone turnover, and renal function.

Participants were randomly assigned to a low-fat, high-protein (HP) or low-fat, high-carbohydrate (HC) regimen for 12 weeks. The HP regimen consisted of 34% total calories from protein, 20% from fat (<10% saturated fat), and 46% from carbohydrate. The HC diet consisted of 17% of total calories from protein, 20% from fat (<10% from saturated fat), and 64% from carbohydrate. Both dietary regimens were designed to provide the same total energy intake of ~1340 kcals). This calorie level was adjusted for very active participants to ensure that they did not exceed the expected weight loss of ~1 kg/wk for the first 2-3 weeks of the study.

All participants were provided with 6 meals per week (isocaloric between HP and HC groups). For the HP group, these meals emphasized lean red meat, lunch meat, chicken, and fish. Meals provided to the HC group emphasized smaller amounts of chicken and pork in addition to pasta, rice, biscuits, and whole-meal bread. The researchers required participants in the HP group to consume 200 g of red meat and 100 g of chicken, fish, or lunch meat daily. Participants in the HC group were required to consume 80 g of chicken or pork plus the bread provided each day. Consistent with a "quasi ad libitum" approach, additional foods were to be consumed according to appetite, but participants were asked not to exceed predetermined amounts. The women were asked to keep detailed food intake records and met with a dietitian every 4 weeks for nutritional counseling and analysis of intake.

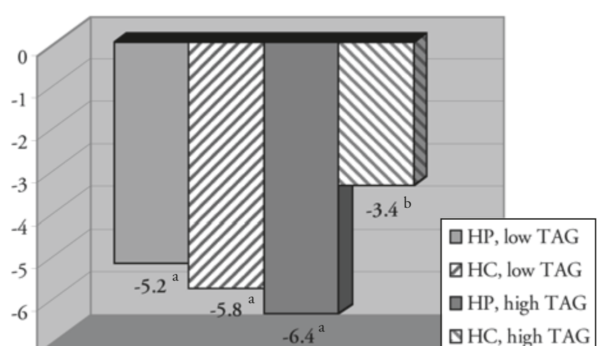
Weight, BMI, body composition (measured by DEXA), urinary output, serum lipids, insulin, and C-reactive protein (CRP) were measured and recorded throughout the study. Homocysteine, iron, ferritin, folate, vitamin B-6, and vitamin B-12 levels were also obtained at baseline and at 12 weeks to determine the diets' impact on nutritional status.

Intakes of total calories, alcohol, and fiber were similar between diet groups. Participants in the HP group consumed more total, saturated, and monounsaturated fat. Cholesterol intake was also higher for the HP group. However, participants in the HC diet group consumed less thiamin, riboflavin, niacin, calcium, and iron than those in the HP group.

Weight loss was similar between the HP and HC diet groups (7.6±0.4 kg and 6.9±0.5 kg, respectively; P=0.29). However, weight loss differed significantly between groups for participants with high triacylglycerol (TAG) concentrations (>1.5 mmol/L). Participants with high TAG concentrations in the HP group lost an average of 25% more body weight than those in the HC group (P=0.005).

Changes in body composition (fat vs. lean mass) were also similar between groups, but again, a significant difference was observed between women with high TAG concentrations in the HP and HC groups. Those following the HP regimen lost an average of 6.4±0.7 kg body fat, while those in the HC group lost only 3.4±0.7 kg (P=0.035).

The diets did not appear to have any differential effects on renal function, serum lipids, or glucose concentrations; however, LDL cholesterol, HDL cholesterol, and glucose concentrations dropped for participants in both diet groups. There were significant differences in TAG concentrations between groups, with decreases of 8% and 22% for women in the HC and HP groups, respectively. However, when the data were analyzed based on initial TAG levels, women with low TAG at baseline did not experience any diet-related changes in TAG, while women with high baseline TAG in the HP group experienced significantly greater



Change in Body Weight (kg)
(values with differing superscripts are significantly different; p=0.035)

decreases in TAG than those in the HC group (28% for HP vs. 10% for HC).

With regard to nutritional status, vitamin B-12 rose by 9% in women following the HP regimen and decreased by 13% in those following the HC regimen. Vitamin B-6 increased similarly for both groups and no significant changes in homocysteine or iron status were observed. These observations do not support the thought that high-protein diets impair bone mineral density or renal function, as changes in markers of bone turnover and renal function were similar between groups.

In studies conducted previously by the same group of researchers, participants with type 2 diabetes and hyperinsulinemia lost more weight on a high-protein diet than they lost on a high-carbohydrate diet. Thus, the observations in the current study that weight loss did not differ between diet groups in this cohort of overweight women were unexpected. However, Noakes et al. observed that women with high TAG concentrations (a marker for insulin resistance syndrome) did respond as expected, with greater losses in response to the HP vs. the HC diet regimen. These novel observations suggest that differential responses to dietary change are modified by phenotype.

Noakes M, Keogh JB, Foster PR, Clifton PM. Effect of an energy-restricted, high-protein, low-fat diet relative to a conventional high-carbohydrate, low-fat diet on weight loss, body composition, nutritional status, and markers of cardiovascular health in obese women. *Am J Clin Nutr* 2005;81:1298-1306.

Dietary Lutein and Zeaxanthin Associated with Macular Pigment Density

Macular pigment, composed of lutein (L), zeaxanthin (Z), and mesozeaxanthin (MZ), is thought to act as a filter, protecting the sensitive macula (a small region of the retina) from photodamage. Macular pigment is also thought to help prevent debilitating eye diseases such as macular degeneration. Lutein and zeaxanthin are not produced endogenously. These important carotenoids can only be obtained from dietary sources, thus, intake of lutein and zeaxanthin is thought to be of high importance in ensuring optimal macular pigment optical density (MPOD). Other factors such as body fat stores, age, and gender are also thought to regulate or mediate the deposition of lutein and zeaxanthin in the macula.

Burke et al. measured dietary intake and serum concentrations of lutein and zeaxanthin in 98 study participants to evaluate the relationship between diet and macular pigment (MP) status. Healthy adults between the ages of 45 and 75 years were eligible to participate in this study. Height and weight were measured and BMI was calculated for each participant. A 122-item food-frequency questionnaire was completed by each participant to evaluate eating habits and lutein and zeaxanthin intake (reported as L+Z). In addition, the Block Eating Habits Screener was used to assess fruit and vegetable intake. According to this instrument, consumption of <3 servings of fruit and vegetables per day was considered "low," intake of <4 servings per day was considered "medium," and consumption of 5 or more servings a day was considered "high" or "very high." All participants were evaluated for visual acuity and retinal integrity and MPOD was measured at several sites.

Reported intakes of L+Z were positively associated with MPOD at all sites measured ($P< 0.02$). Serum concentrations of L+Z were also positively correlated with MPOD at the three most central sites ($P<0.008$). Fruit and vegetable intake scores (from the Block Eating Habits Screener) were positively associated with reported intakes of L+Z ($r=0.35$, $P=0.001$) and MPOD ($P<0.02$ for most sites measured). Those in the lowest quartile of fruit and vegetable intake had the lowest measured MPOD, while those in the highest quartile had the highest.

Although reported intakes of beta carotene and L+Z were higher for women, MPOD did not differ between men and women at any site. When divided into quartiles based on age, there were no differences in MPOD between groups. BMI made no difference when analyzed as a continuous variable; however, participants whose BMIs fell below 27 kg/m^2 had greater MPOD at all sites than those with BMI scores >27 kg/m^2.

The researchers noted three significant outcomes in this study. First, the observations suggest that MPOD is positively associated with both dietary intake and serum concentrations of lutein and zeaxanthin. Second, higher intakes of fruits and vegetables appear to increase MPOD. Third, participants with lower BMI scores (<27 kg/m^2) had significantly higher MPOD than those with BMI scores >27 kg/m^2 at two sites. These outcomes suggest that dietary intake of L+Z from fruits and vegetables (among other sources) might be useful as a potential preventive measure and/or treatment for eye diseases such as macular degeneration. They also suggest that keeping one's BMI in check might also help protect the retina by allowing greater deposition of lutein and zeaxanthin in the macula.

Burke JD, Curran-Celentano J, and Wenzel AJ. Diet and serum carotenoid concentrations affect macular pigment optical density in adults 45 years and older. *J Nutr* 2005;135(5):1208-1214.

Twins Respond Similarly to Changes in Diet

Although the medical community has increasingly turned to pharmacotherapy for regulation of blood lipids, health professionals have largely maintained their emphasis on traditional dietary approaches (such as limiting intake of dietary fat) to manage dyslipidemia. Lipid responses to dietary modifications differ greatly, however, and individual responses to dietary fat restriction are particularly variable. For example, certain genetic polymorphisms have been found to mediate lipid responses to low-fat diets. Such research has led clinicians to question whether the low-fat approach is appropriate as a general recommendation for improving lipid profiles.

To expand upon this growing body of genetic research, Williams et al. undertook a crossover study designed to compare biochemical and anthropometric responses to changes in dietary intake among identical (monozygotic) male twins. Study administrators selected twins based on disparities in physical activity to minimize the environmental impact on responses to dietary modification. Twin pairs were eligible for the study if one was sedentary and the other ran >32 km/week or if both twins were runners and one customarily ran at least 40 km/wk more than his twin. A total of 29 pairs of twins were eligible for participation in the study.

Pairs were randomly assigned to a high-fat, low-carbohydrate diet or a low-fat, high-carbohydrate diet for the first 6 weeks of the study. The high-fat (HF) diet consisted of 40% of total calories from fat and 45% from carbohydrate, while the low-fat (LF) diet provided only 20% of total calories from fat and 65% from carbohydrate. Individually prescribed diets provided 95% of each participant's total calorie needs (based on a 4-day food record completed at baseline) and were designed to isolate changes in fat and carbohydrate intake while keeping the intake of all other nutrients as similar as possible. Participants were expected to consume all foods prescribed and were asked to consume the remaining 5% of total calories according to appetite. This 5% of calories was to be chosen from a pre-determined selection of foods—1/2 cup of low-fat milk and 5 vanilla wafers for the LF diet group or 1 teaspoon peanut butter with 8 wheat crackers for the HF diet group. Participants had blood drawn at local laboratories at baseline and following each diet phase to provide a measurement of fasting plasma lipids, LDL particle sizes, and apo A-I and B concentrations.

The running twins reported running an average of 50 km/week more than the sedentary twins, and as expected, the running twins had much less atherogenic lipid profiles than their sedentary counterparts at baseline. Plasma concentrations of triacylglycerol (TAG) and apo-B were significantly lower in the running twins, while LDL peak particle diameter, apo A-I levels, and HDL-cholesterol concentrations were significantly higher. The running twins also weighed significantly less than the sedentary twins. Despite the statistical significance of these differences between running and sedentary twins, all of the aforementioned measures [in addition to total cholesterol, LDL cholesterol, and lipoprotein(a)] were strongly correlated between brothers.

According to diet records, changes in intake of energy, total fat, saturated, monounsaturated, and polyunsaturated fat, carbohydrates, protein, and cholesterol were similar between twins when switching from one diet phase to the other. The overall effect of reducing fat intake and increasing the proportion of carbohydrate was similar in both the running and the sedentary twins. HDL-cholesterol concentrations dropped and mean LDL peak particle diameter and peak flotation rates decreased, as well as the concentration of large LDL particles. Changes in body weight in response to the diets were highly variable, yet highly correlated within twin pairs ($r=0.41$; $P<0.05$). Also significantly correlated were changes in total cholesterol ($r=0.56$), apo A-I ($r=0.49$), lipoprotein(a) ($r=0.49$), LDL cholesterol ($r= 0.70$), and large, buoyant LDL particles ($r=0.52$).

Observations from this unique research model suggest that genetic inheritance strongly influences the way the human body responds to changes in fat and carbohydrate intake. Even with extreme differences in physical activity, changes in serum lipids, lipoproteins, and body weight were highly correlated within twin pairs. The authors conclude that more specific genetic research in this area is warranted to identify inherited determinants of such responses to dietary change.

Williams PT, Blanche PJ, Rawlings R, Krauss RM. Concordant lipoprotein and weight responses to dietary fat change in identical twins with divergent exercise levels. *Am J Clin Nutr* 2005;82:181-187.

COMMON ABBREVIATIONS

BMI: body mass index (kg/m^2)	MUFA: monounsaturated fatty acids
WHR: waist-hip ratio	PUFA: polyunsaturated fatty acids
CHO: carbohydrate	PVD: peripheral vascular disease
CVD: cardiovascular disease	RR: relative risk
HDL: high density lipoprotein	SFA: saturated fatty acids
LDL: low density lipoprotein	TAG: triacylglycerol
Lp(a): lipoprotein (a)	VLDL: very low density lipoprotein

Protein Intake Associated with Reduced Abdominal Adiposity

Waist-hip ratio (WHR) is a measurement frequently used as a surrogate indicator of visceral abdominal fat stores. Although it correlates strongly with excess body weight, abdominal obesity is independently associated with insulin resistance, subclinical atherosclerosis, low HDL cholesterol, and high triacylglycerols; and it stands alone as a risk factor for diabetes, heart disease, stroke, and death. A few cross-sectional studies have shown a negative correlation between abdominal fat stores and intake of fish, chicken, fiber, and polyunsaturated fats and a positive correlation with intake of *trans* fats. But few, if any, studies have evaluated abdominal adiposity as it relates to macronutrient distribution. Motivated by this gap in research, Merchant et al. undertook a cross-sectional study to determine whether abdominal adiposity is related to macronutrient intake.

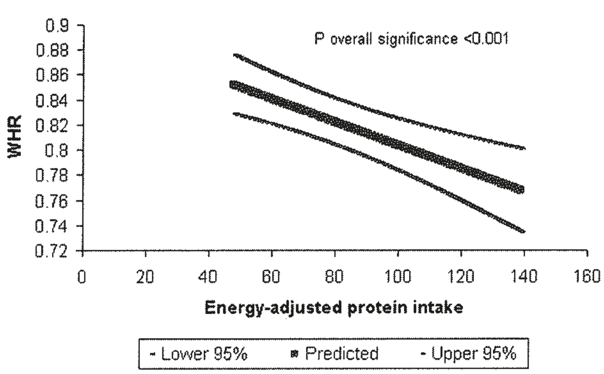
Study administrators evaluated Canadian data obtained from two cross-sectional studies, the Study of Health Assessment and Risk in Ethnic groups (SHARE) and the Study of Health Assessment and Risk Evaluation in Aboriginal Peoples (SHARE-AP). Participants included aboriginal Canadians and Canadians of south Asian, Chinese, and European origin. All were between 35 and 75 years of age.

Height, weight, waist circumference, and hip circumference were recorded for each participant and dietary intake was determined using validated, culture-specific, semiquantitative food frequency questionnaires. Participants with serious chronic diseases were excluded, as well as those whose reported dietary energy intakes were extremely high or low.

Researchers analyzed data that had been gathered from a total of 617 participants (15% Aboriginal, 28% South Asian, 27% Chinese, 30% European). Evaluations of these data showed positive correlations between WHR and age, smoking, male gender, and, predictably, BMI. An inverse association was observed between WHR and physical activity. Higher protein intake was linearly related to lower WHR after adjusting for covariates (age, total daily energy intake, height, physical activity score, sex, BMI, smoking status, alcohol intake, and ethnic origin; $P<0.001$). This relationship was strengthened after further adjusting for fiber intake and was not affected by adjusting for ethnicity. Multivariate analysis also demonstrated that replacing carbohydrate with an equivalent amount of protein was associated with lower WHR; however, no association was observed when carbohydrate was replaced with fat.

Although the authors recognize that their relatively small sample size limits the application of these findings, their observations suggest that replacing dietary carbohydrates with protein, even in relatively small amounts, might contribute to a reduction in excess abdominal fat. The authors speculate that this association might be related to several benefits of increased protein intake, including enhanced satiety, increased postprandial thermogenesis, improved intake of conjugated linoleic acid (found in dairy products and beef), and improved insulin sensitivity.

Merchant AT, Anand SS, Vuksan V, et al. Protein intake is inversely associated with abdominal obesity in a multi-ethnic population. *J Nutr* 2005;135(5):1196-1201.



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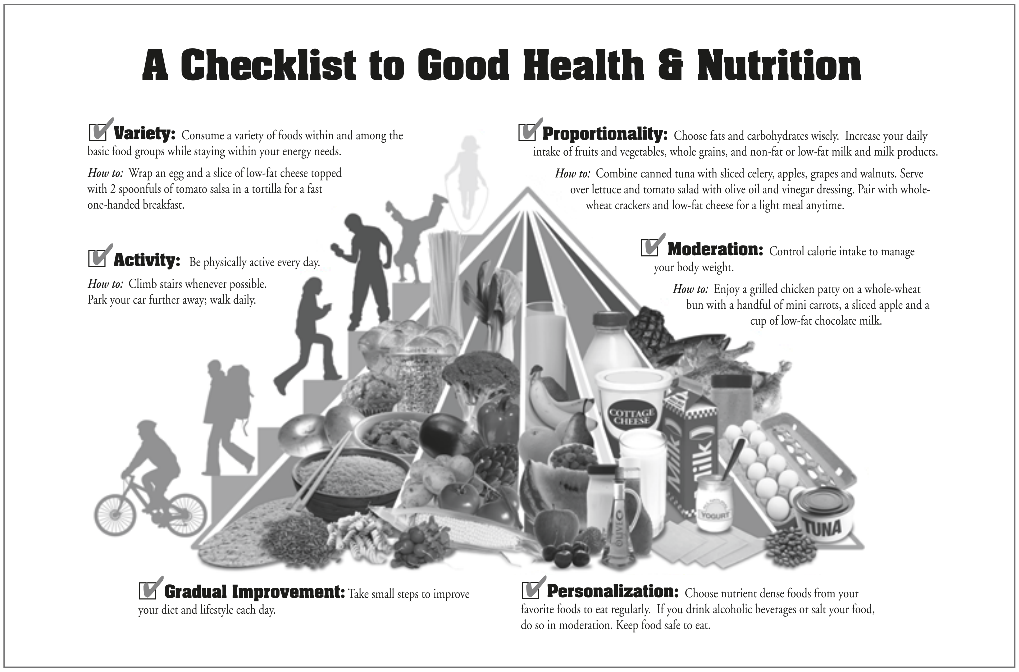

New Pyramid Poster

The Egg Nutrition Center is pleased to announce the availability of a new educational piece entitled, "A Checklist to Good Health and Nutrition." This new graphic representation, based on USDA's MyPyramid, replaces the Egg Nutrition Center's popular "Pyramid Power Meal" and is available for download in English and Spanish on our website (www.enc-online.org). Single copies are also available through our office. Please contact us at enc@enc-online.org to request your complimentary copy, or better yet, come visit our booth (#1224) at FNCE 2005, October 22-25, in St. Louis. See you there!

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