ORIGINAL ARTICLE

A Randomized Trial of a Low-Carbohydrate Diet for Obesity

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ABSTRACT

BACKGROUND

Despite the popularity of the low-carbohydrate, high-protein, high-fat (Atkins) diet, no randomized, controlled trials have evaluated its efficacy.

METHODS

We conducted a one-year, multicenter, controlled trial involving 63 obese men and women who were randomly assigned to either a low-carbohydrate, high-protein, high-fat diet or a low-calorie, high-carbohydrate, low-fat (conventional) diet. Professional contact was minimal to replicate the approach used by most dieters.

RESULTS

Subjects on the low-carbohydrate diet had lost more weight than subjects on the conventional diet at 3 months (mean [±SD], −6.8±5.0 vs. −2.7±3.7 percent of body weight; P=0.001) and 6 months (−7.0±6.5 vs. −3.2±5.6 percent of body weight, P=0.02), but the difference at 12 months was not significant (−4.4±6.7 vs. −2.5±6.3 percent of body weight, P=0.26). After three months, no significant differences were found between the groups in total or low-density lipoprotein cholesterol concentrations. The increase in high-density lipoprotein cholesterol concentrations and the decrease in triglyceride concentrations were greater among subjects on the low-carbohydrate diet than among those on the conventional diet throughout most of the study. Both diets significantly decreased diastolic blood pressure and the insulin response to an oral glucose load.

CONCLUSIONS

The low-carbohydrate diet produced a greater weight loss (absolute difference, approximately 4 percent) than did the conventional diet for the first six months, but the differences were not significant at one year. The low-carbohydrate diet was associated with a greater improvement in some risk factors for coronary heart disease. Adherence was poor and attrition was high in both groups. Longer and larger studies are required to determine the long-term safety and efficacy of low-carbohydrate, high-protein, high-fat diets.

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At any given time, approximately 45 percent of women and 30 percent of men in the United States are trying to lose weight.[1] Despite these efforts, the prevalence of obesity has doubled in the past 20 years[2] and has become a major public health problem.[3] The conventional dietary approach to weight management, recommended by the leading research and medical societies,[4-7] is a high-carbohydrate, low-fat, energy-deficit diet. Low-carbohydrate, high-protein, high-fat diets have become increasingly popular, and many best-selling diet books have promoted this approach.[8,9] The Atkins diet, originally published in 1973 and again in 1992 and 2002, may be the most popular of these diets. More than 10 million copies of Atkins's diet book have been sold,[10] and four times as many dieters have read one of the Atkins books as have read any other diet book.[11]

Despite its longevity and popularity, no randomized trials evaluating the efficacy of the Atkins diet have been published.[12,13] Data from short-term, uncontrolled studies indicate that the Atkins diet induces weight losses of 8.3 percent after 8 weeks[14] and 10.3 percent after 24 weeks.[15]

We conducted a one-year, multicenter, randomized, controlled trial to evaluate the effect of the low-carbohydrate, high-protein, high-fat Atkins diet on weight loss and risk factors for coronary heart disease in obese persons. The subjects were randomly assigned to follow either a low-carbohydrate, high-protein, high-fat Atkins diet or a high-carbohydrate, low-fat, energy-deficit conventional diet. Professional contact was minimal, so as to approximate the approach used by most dieters.

METHODS

SUBJECTS

A total of 63 persons (43 women and 20 men) participated in the study (Table 1). All subjects completed a comprehensive medical examination and routine blood tests. Potential subjects were excluded if they had clinically significant illnesses, including type 2 diabetes; were taking lipid-lowering medications; were pregnant or lactating; or were taking medications that affect body weight. All subjects provided written informed consent, and the protocol was approved by the institutional review boards of the participating institutions.

STUDY DESIGN

The subjects were randomly assigned at each site, with use of a random-number generator, to follow either the low-carbohydrate diet or the conventional diet. Subjects in both groups were instructed to take a daily multivitamin supplement and met with a registered dietitian for 15 to 30 minutes at 3, 6, and 12 months to review dietary issues.

Low-Carbohydrate Diet

The 33 subjects who were assigned to the low-carbohydrate, high-protein, high-fat diet met individually with a registered dietitian before beginning the program to review the central features of the diet (available as Supplementary Appendix 1 with the full text of this article at http://www.nejm.org), which involves limiting carbohydrate intake without restricting consumption of fat and protein. For the first two weeks, carbohydrate intake is limited

Table 1. Base-Line Characteristics of the Subjects.*

Characteristic	Low-Carbohydrate Diet (N=33)	Conventional Diet (N=30)
Sex (no. of subjects)		
Male	12	8
Female	21	22
Race or ethnic group (no. of subjects)†		
White	26	22
Black	4	8
Hispanic	3	0
Age (yr)	44.0±9.4	44.2±7.0
Body-mass index‡	33.9±3.8	34.4±3.1
Weight (kg)	98.7±19.5	98.3±16.4
Systolic blood pressure (mm Hg)	120.5±11.0	123.3±14.1
Diastolic blood pressure (mm Hg)	74.6±8.5	77.6±10.8
Triglycerides (mg/dl)	131.1±113.8	122.6±82.6
Cholesterol (mg/dl)		
Total	200.5±33.5	193.7±32.1
Low-density lipoprotein	129.5±30.0	119.8±30.0
High-density lipoprotein	46.8±11.2	49.4±12.5
Area under the curve		
Glucose (mg/dl/2 hr)	15,649.7±2956.3	15,540.2±2623.8
Insulin (μU/ml/2 hr)	8776.7±5072.5	10,025.7±5845.5
Insulin sensitivity§	0.35±0.05	0.34±0.04

* Plus–minus values are means ±SD. There were no significant differences between the two groups. To convert values for triglycerides to millimoles per liter, multiply by 0.01129. To convert values for cholesterol to millimoles per liter, multiply by 0.02586.
† The race or ethnic group was assigned by the subjects themselves.
‡ The body-mass index is the weight in kilograms divided by the square of the height in meters.
§ Insulin sensitivity was calculated according to the quantitative insulin-sensitivity check index.[16]

Table 2. Percent Changes in Weight, Blood Pressure, Serum Lipoprotein Concentrations, and Oral Glucose Tolerance in an Analysis in Which Base-Line Values Were Carried Forward in the Case of Missing Data.*

Variable	Low-Carbohydrate Diet (N=33)	Conventional Diet (N=30)	P Value†
	percent change		
Weight			
Mo 3	−6.8±5.0‡	−2.7±3.7‡	0.001
Mo 6	−7.0±6.5‡	−3.2±5.6‡	0.02
Mo 12	−4.4±6.7‡	−2.5±6.3‡	0.26
Systolic blood pressure			
Mo 3	−2.6±11.2	−0.6±11.9	0.59
Mo 6	−2.3±11.7	1.0±12.2	0.28
Mo 12	−1.0±9.4	1.7±11.8	0.43
Diastolic blood pressure			
Mo 3	−3.0±13.4	−3.5±10.3‡	0.84
Mo 6	−4.0±12.7‡	−2.9±14.2	0.84
Mo 12	−3.7±12.4‡	−3.8±13.2	0.84
Triglycerides			
Mo 3	−18.7±25.7‡	1.1±34.6	0.01
Mo 6	15.0±29.4‡	−7.6±19.3‡	0.13
Mo 12	−17.0±23.0‡	0.7±37.7	0.04
Total cholesterol			
Mo 3	1.7±15.0	−5.4±10.1‡	0.03
Mo 6	2.4±9.3	−2.4±9.5	0.06
Mo 12	0.1±9.8	−2.9±8.0	0.27
Low-density lipoprotein cholesterol			
Mo 3	5.4±19.2	−7.4±16.6‡	0.007
Mo 6	2.7±12.8	−1.5±15.8	0.34
Mo 12	0.31±16.6	−3.1±12.0	0.52
High-density lipoprotein cholesterol			
Mo 3	9.6±19.1‡	1.4±16.1	0.04
Mo 6	14.7±20.5‡	2.5±12.0	0.007
Mo 12	11.0±19.4‡	1.6±11.1	0.04
Area under the glucose curve			
Mo 3	6.7±20.7	1.6±16.6	0.27
Mo 6	1.0±15.9	−0.8±12.2	0.80
Mo 12	3.2±16.2	1.2±10.1	0.80
Area under the insulin curve			
Mo 3	−14.1±27.6‡	−11.2±40.5‡	0.48
Mo 6	−14.7±25.7‡	−5.1±35.8	0.19
Mo 12	−11.2±24.7‡	−8.2±28.4‡	0.60
Insulin sensitivity§			
Mo 3	6.7±11.6‡	4.1±10.7	0.37
Mo 6	5.8±12.0‡	5.2±10.3‡	0.79
Mo 12	2.9±9.5	2.9±9.5	0.92

* Plus–minus values are means ±SD.
† P values are for the differences between the two groups.
‡ P<0.05 for the difference from base line within the group.
§ Insulin sensitivity was calculated according to the quantitative insulin-sensitivity check index.[16]

to 20 g per day and is then gradually increased until a stable and desired weight is achieved. Each subject was given a copy of *Dr. Atkins' New Diet Revolution*,[10] which details the Atkins diet program. Subjects were instructed to read the book and follow the diet as described.

Conventional Diet

The 30 subjects who were assigned to the conventional diet also met with a registered dietitian before beginning the program to review the components of a high-carbohydrate, low-fat, low-calorie diet (1200 to 1500 kcal per day for women and 1500 to 1800 kcal per day for men, with approximately 60 percent of calories from carbohydrate, 25 percent from fat, and 15 percent from protein) and to receive instructions about calorie counting. Subjects were given a copy of *The LEARN Program for Weight Management*,[17] which provides 16 lessons covering various aspects of weight control. The nutritional information in the manual was consistent with the dietary recommendations provided by the study dietitian and with the Department of Agriculture Food Guide Pyramid.[18] Subjects were instructed to read the manual and follow the program as described.

OUTCOMES

Body weight was measured with the use of calibrated scales (Detecto 6800, Cardinal) while the subjects were wearing light clothing and no shoes at base line and at weeks 2, 4, 8, 12, 16, 20, 26, 34, 42, and 52. Blood pressure and urinary ketones were also assessed at base line and at weeks 2, 4, 8, 12, 16, 20, 26, 34, 42, and 52. Blood samples were obtained after subjects fasted overnight at base line and at 3, 6, and 12 months to determine serum lipoprotein concentrations. An oral glucose-tolerance test was performed at base line and at 3, 6, and 12 months. After subjects fasted overnight, blood samples were obtained for the measurement of plasma glucose and insulin concentrations before and 30, 60, 90, and 120 minutes after the oral administration of a 75-g glucose load. In addition, insulin sensitivity, based on fasting plasma glucose and insulin concentrations, was assessed with the use of quantitative insulin-sensitivity check index[16]: $1 \div [(\log \text{fasting serum insulin level, in microunits per milliliter}) + (\log \text{fasting glucose level, in milligrams per deciliter})]$.

ANALYSES OF SAMPLES

Serum total cholesterol, high-density lipoprotein (HDL) cholesterol, and triglyceride concentrations

were assayed according to procedures recommended by the Centers for Disease Control and Prevention and the National Heart, Lung, and Blood Institute.[19] The low-density lipoprotein (LDL) cholesterol concentration was calculated according to the Friedewald formula[20] in all but one subject, who had a triglyceride concentration greater than 400 mg per deciliter (4.52 mmol per liter). Plasma insulin was measured by radioimmunoassay, and plasma glucose by a glucose oxidase autoanalyzer (Yellow Springs Instruments). The area under the curve (AUC) for the plasma glucose concentration and for the insulin concentration was calculated.[21] Urinary ketone concentrations were measured with dipsticks (Ketostix 2880, Bayer) and characterized dichotomously as negative (0 mg per deciliter) or positive (5 to 100 mg per deciliter).

STATISTICAL ANALYSIS

Analysis of variance revealed no effects of the research site on weight loss or attrition at 3, 6, or 12 months, so the data on all the subjects were analyzed together. A t-test for independent samples was used to assess differences in base-line variables between the groups. Two sets of analyses were conducted. The primary analysis was a repeated-measures analysis of variance in which the base-line value was carried forward in the case of missing data. In a secondary analysis, an analysis of covariance (in which initial weights were covariates) was used to examine changes in weight from base line to the end of the study, for those who completed the study, or at the time of the last follow-up visit, for those who did not complete the study. A chi-square analysis was performed to determine differences between groups in categorical variables, and correlations with categorical variables were assessed with Spearman's rho coefficient. Triglyceride values were not normally distributed, so the log-transformed values were analyzed. Results are presented as percent changes to facilitate clinical interpretation, although all analyses involved absolute values and were conducted with the use of SPSS software (version 11.0).[22]

RESULTS

WEIGHT

In the analysis in which base-line values were carried forward in the case of missing values, the group on the low-carbohydrate diet had lost significantly more weight than the group on the conventional diet at 3 months (P=0.001) and 6 months (P=0.02), but the difference in weight loss was not statistically significant at 12 months (P=0.26) (Table 2 and Fig. 1A).

ATTRITION

A total of 49 subjects completed 3 months of the study (28 on the low-carbohydrate diet and 21 on the conventional diet), 42 subjects completed 6 months (24 on the low-carbohydrate diet and 18 on the conventional diet), and 37 subjects completed 12 months (20 on the low-carbohydrate diet and 17 on the conventional diet). The percentage of subjects who had dropped out of the study at 3, 6, and 12 months was higher in the group following the conventional diet (30, 40, and 43 percent, respectively) than in the group following the low-carbohydrate diet (15, 27, and 39 percent, respectively), but these differences were not statistically significant. Overall, 59 percent of subjects completed the study, and 88 percent of those who completed the

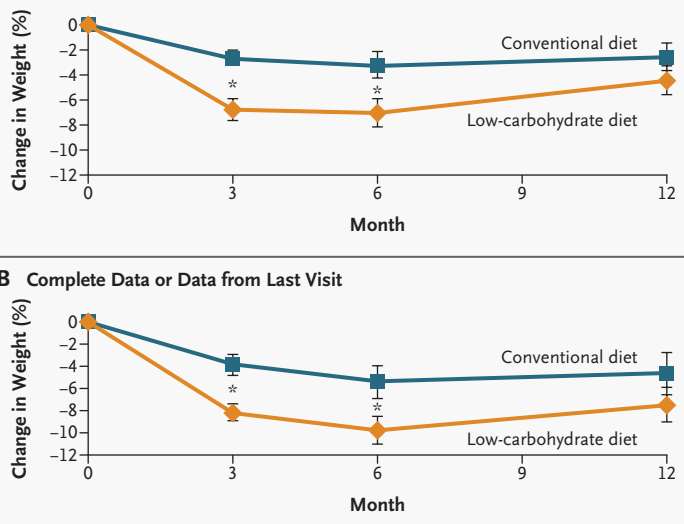

Figure 1. Mean (±SE) Percent Change in Weight among Subjects on the Low-Carbohydrate Diet and Those on the Conventional (Low-Calorie, High-Carbohydrate) Diet, According to an Analysis in Which Base-Line Values Were Carried Forward in the Case of Missing Values (Panel A) or an Analysis That Included Data on Subjects Who Completed the Study and Data Obtained at the Time of the Last Follow-up Visit for Those Who Did Not Complete the Study (Panel B).

In Panel B, the low-carbohydrate group had 28 subjects at 3 months, 24 subjects at 6 months, and 20 subjects at 12 months and the conventional-diet group had 21 subjects at 3 months, 18 subjects at 6 months, and 17 subjects at 12 months. Asterisks indicate a significant difference (P<0.05) between the groups.

Table 3. Percent Changes in Weight, Blood Pressure, Serum Lipoproteins, and Oral Glucose Tolerance in an Analysis That Included Data on Subjects Who Completed the Study and Data Obtained at the Time of the Last Follow-up Visit for Those Who Did Not Complete the Study.*

Variable	Low-Carbohydrate Diet	Conventional Diet	P Value†
	percent change		
Weight			
Mo 3	−8.1±4.4‡	−3.8±3.9‡	0.002
Mo 6	−9.7±5.7‡	−5.3±6.4‡	0.03
Mo 12	−7.3±7.3‡	−4.5±7.9‡	0.27
Systolic blood pressure			
Mo 3	−3.1±12.1	−0.8±14.3	0.69
Mo 6	−3.2±12.7	1.6±15.9	0.36
Mo 12	−1.6±12.2	2.9±15.8	0.44
Diastolic blood pressure			
Mo 3	−3.5±14.5	−5.1±12.1‡	0.65
Mo 6	−5.5±14.7‡	−4.9±18.3	0.95
Mo 12	−6.1±15.6‡	−6.7±17.2	0.76
Triglycerides			
Mo 3	−22.0±26.6‡	1.7±42.8	0.03
Mo 6	−20.6±32.8‡	−13.3±24.3‡	0.27
Mo 12	−28.1±23.6‡	1.4±52.5	0.04
Total cholesterol			
Mo 3	2.0±16.3	−8.2±11.5‡	0.02
Mo 6	3.3±10.9	−4.2±12.5	0.06
Mo 12	0.2±12.7	−5.5±10.4	0.23
Low-density lipoprotein cholesterol			
Mo 3	6.2±20.4	−11.1±19.4‡	0.005
Mo 6	3.6±14.8	−2.7±21.1	0.35
Mo 12	0.5±21.2	−5.8±16.1	0.47
High-density lipoprotein cholesterol			
Mo 3	11.4±20.3‡	2.1±19.8	0.07
Mo 6	20.2±21.7‡	4.4±15.8	0.02
Mo 12	18.2±22.4‡	3.1±15.2	0.04
Area under the glucose curve			
Mo 3	7.9±22.3	2.3±19.9	0.33
Mo 6	1.4±18.7	−1.4±16.5	0.76
Mo 12	5.3±20.8	2.4±14.4	0.87
Area under the insulin curve			
Mo 3	−16.7±29.3‡	−16.0±48.0‡	0.23
Mo 6	−20.2±28.4‡	−9.0±47.8	0.37
Mo 12	−18.4±29.8‡	−16.5±39.1‡	0.34
Insulin sensitivity§			
Mo 3	7.9±12.3‡	5.9±12.4	0.56
Mo 6	8.0±13.4‡	8.7±12.1‡	0.94
Mo 12	4.8±12.0	5.4±12.7	0.98

* Plus–minus values are means ±SD. The low-carbohydrate group had 28 subjects at 3 months, 24 subjects at 6 months, and 20 subjects at 12 months. The conventional-diet group had 21 subjects at 3 months, 18 subjects at 6 months, and 17 subjects at 12 months.
† P values are for the differences between the two groups.
‡ P<0.05 for the difference from base line within the group.
§ Insulin sensitivity was calculated according to the quantitative insulin-sensitivity check index.[16]

six-month assessment completed the full study. When the analysis included data on subjects who completed the study and data obtained at the time of the last follow-up visit for those who did not complete the study, the pattern of weight loss was similar to that obtained when the base-line values were carried forward in the case of missing data. Subjects on the low-carbohydrate diet lost significantly more weight than the subjects on the conventional diet at 3 months (P=0.002) and 6 months (P=0.03), but the difference in weight loss was not statistically significant at 12 months (P=0.27) (Table 3 and Fig. 1B).

URINARY KETONES

During the first three months, the percentage of patients who tested positive for urinary ketones was significantly greater in the group on the low-carbohydrate diet than in the group on the conventional diet (Fig. 2), but there were no significant differences between the groups after three months. There was no significant relation between weight loss and ketosis at any time during the study.

BLOOD PRESSURE

Systolic blood pressure did not change significantly in either group during the study (Tables 2 and 3). Diastolic pressure decreased in both groups, but there were no significant differences between groups.

ORAL GLUCOSE-TOLERANCE TEST

The area under the glucose curve did not change significantly in either group throughout the study. The area under the insulin curve decreased in both groups, but there were no significant differences between groups (Tables 2 and 3). There were no significant differences between groups in insulin sensitivity (assessed by the quantitative insulin-sensitivity check index[16]) throughout the study period. Both groups had significant increases in insulin sensitivity at six months, but the values were not significantly different from base line at one year (Tables 2 and 3).

SERUM LIPOPROTEINS

The effects of the diets on serum lipoproteins are shown in Tables 2 and 3 and Figure 3. There were no significant differences between groups in the total or LDL cholesterol concentration, except at month 3, when values were significantly lower in the group on the conventional diet than in the group on the low-carbohydrate diet. In contrast, the rela-

tive increase in HDL cholesterol concentrations and the relative decrease in triglyceride concentrations were greater in the group on the low-carbohydrate diet than in the group on the conventional diet throughout most of the study. The results of the analyses that included data on subjects who completed the study and data obtained at the time of the last follow-up visit for those who did not complete the study (Table 3) were nearly identical to the analyses in which base-line values were carried forward in the case of missing data (Table 2) with respect to blood pressure, insulin sensitivity, and serum lipoproteins.

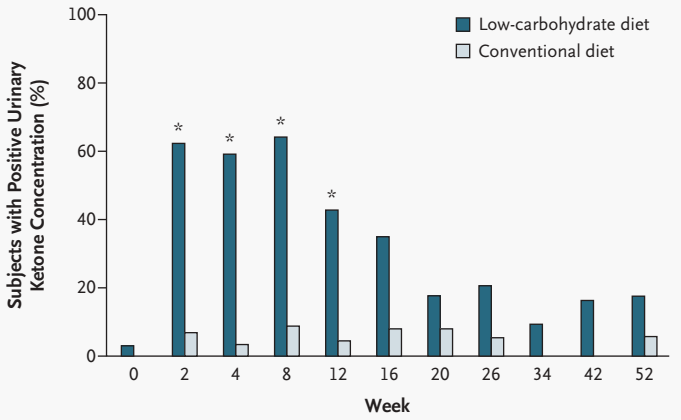

Figure 2. Percentage of Subjects with a Positive Urinary Ketone Concentration, According to Whether They Were on the Low-Carbohydrate Diet or the Conventional (Low-Calorie, High-Carbohydrate) Diet.

A positive urinary ketone concentration was defined as 5 to 100 mg per deciliter. Asterisks indicate a significant difference (P<0.003) between the groups.

DISCUSSION

The results of this multicenter, randomized, controlled trial demonstrate that the low-carbohydrate, high-protein, high-fat Atkins diet produces greater weight loss (an absolute difference of approximately 4 percent) than a conventional high-carbohydrate, low-fat diet for up to six months, but that the differences do not persist at one year. The magnitude of weight loss at six months in the low-carbohydrate group approximates that achieved by standard behavioral[23] and pharmacologic[24] treatments. These weight losses are particularly noteworthy because the diet was implemented in a self-help format and subjects had little contact with health professionals. The lack of a statistically significant difference between the groups at one year is most likely due to greater weight regain in the low-carbohydrate group and the small sample size. These data suggest that long-term adherence to the low-carbohydrate Atkins diet may be difficult.

The difference in weight loss between the two groups in the first six months demonstrates an overall greater energy deficit in the low-carbohydrate group, despite unrestricted protein and fat intake in this group and instructions to restrict energy intake in the conventional-diet group. When the energy content of an energy-deficit diet is stable, macronutrient composition does not influence weight loss.[25-28] The mechanism responsible for the decreased energy intake induced by a low-carbohydrate diet with unrestricted protein and fat intake is not known but may be related to the monotony or simplicity of the diet, alterations in plasma or central satiety factors, or other factors that affect appetite and dietary adherence. Our data suggest that ketosis was unlikely to be responsible for the increased weight loss with the low-carbohydrate diet, since we did not find any relation between the presence of urinary ketones and weight loss. Furthermore, urinary ketones were not present in most subjects on either diet after the first six months.

Although subjects with diabetes were excluded from our study, many — if not most — of our subjects, because of their obesity, were probably insulin-resistant with respect to glucose metabolism.[29] Treatment with either diet was associated with an improvement in insulin sensitivity as determined by an oral glucose-tolerance test; progressively less insulin was secreted to maintain the same blood glucose concentrations. These data do not demonstrate an effect of macronutrient composition, independent of weight loss, on insulin sensitivity in obese subjects without diabetes. However, the results of these metabolic studies should be interpreted with caution, given the study's relatively small sample size and the one-year duration. Additional studies in which more precise measures of insulin sensitivity are used are needed to evaluate this issue more carefully.

An important health concern of consuming unrestricted amounts of saturated fat is the potential to increase the LDL cholesterol concentration, which is an established risk factor for coronary heart disease. In fact, at three months, the LDL cholesterol concentration tended to increase in the subjects on the low-carbohydrate diet but decreased in the subjects on the conventional diet, so the difference be-

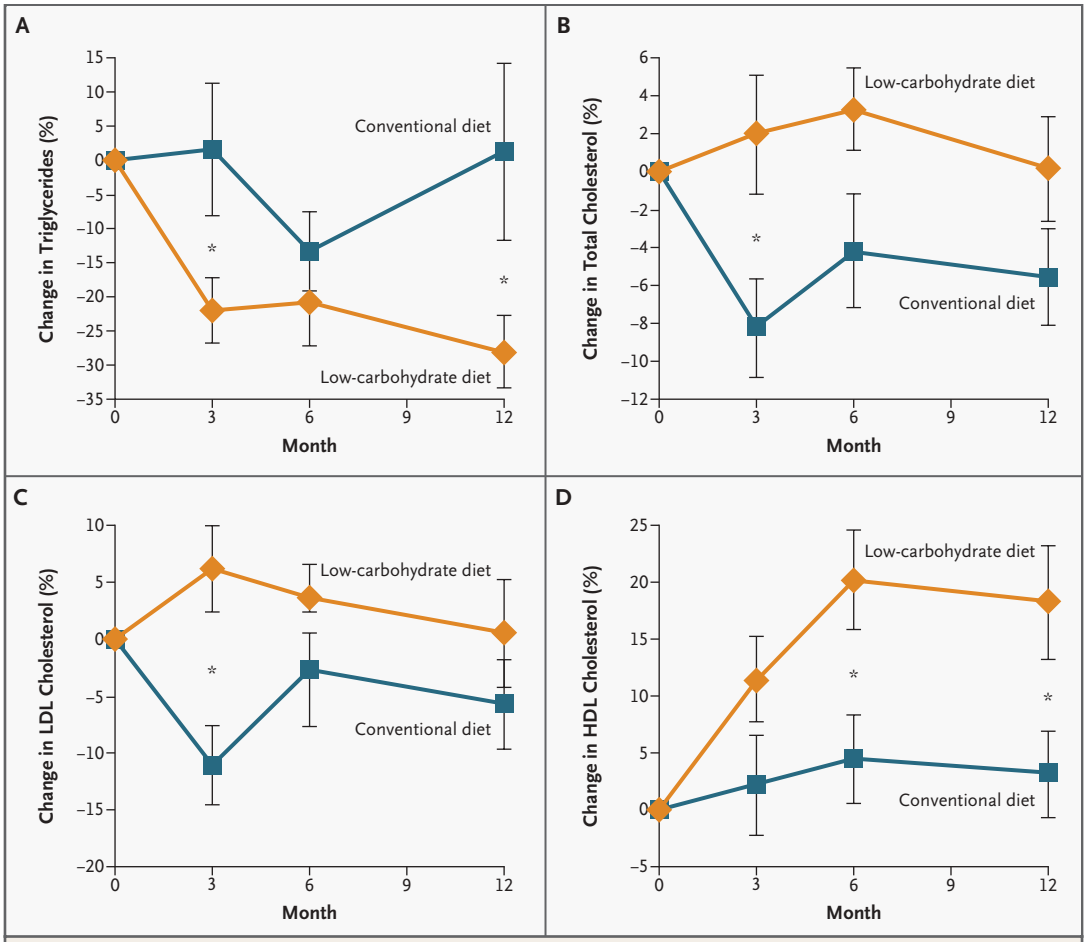

Figure 3. Mean (±SE) Percent Change in Serum Concentrations of Triglycerides (Panel A), Total Cholesterol (Panel B), Low-Density Lipoprotein (LDL) Cholesterol (Panel C), and High-Density Lipoprotein (HDL) Cholesterol (Panel D) among Subjects on the Low-Carbohydrate Diet and Those on the Conventional (Low-Calorie, High-Carbohydrate) Diet.

Data were obtained at the end of the study for subjects who completed the study and at the time of the last follow-up visit for those who did not complete the study. The low-carbohydrate group had 28 subjects at 3 months, 24 subjects at 6 months, and 20 subjects at 12 months. The conventional-diet group had 21 subjects at 3 months, 18 subjects at 6 months, and 17 subjects at 12 months. Asterisks indicate a significant difference ($P<0.05$) between the groups.

tween groups was significant. Over the long term, however, the LDL cholesterol concentration among subjects on the low-carbohydrate diet was similar to base-line values, and the changes in LDL cholesterol concentrations did not differ significantly between the groups. These data suggest that the increased weight loss associated with the low-carbohydrate diet may offset the adverse effect of saturated fat intake on serum LDL cholesterol concentrations. Nonetheless, weight loss with the low-carbohydrate diet was not associated with the decreases in LDL cholesterol usually observed with moderate weight loss.[4,30]

In contrast, the low-carbohydrate diet was associated with greater decreases in serum triglycerides and greater increases in HDL cholesterol than was the conventional diet, and the levels of both are also important risk factors for coronary heart disease.[31-33] The magnitude of these changes approximates that obtained with pharmacologic treatments, such as derivatives of fibric acid and niacin.[31] Although part of this benefit may be due to the greater weight loss with the low-carbohydrate diet, the changes are greater than those expected from a moderate weight loss alone.[30] Therefore, it is likely that the macronutrient composition of the diet

contributed to the improvement in the HDL cholesterol–triglyceride axis. High-carbohydrate, low-fat diets decrease HDL cholesterol concentrations and increase serum triglyceride concentrations,[34-37] whereas low-carbohydrate, high-fat diets decrease triglyceride concentrations[16,27,37] and increase HDL cholesterol concentrations.[15] Moreover, replacing dietary polyunsaturated or monounsaturated fat with carbohydrate is associated with an increased risk of coronary heart disease, as predicted by changes in triglyceride and HDL cholesterol concentrations.[38]

The overall effect of the low-carbohydrate diet in comparison with a conventional diet on the risk of coronary heart disease in our subjects is uncertain. As compared with the conventional diet, the low-carbohydrate diet was associated with a greater improvement in some risk factors for coronary heart disease (serum triglycerides and serum HDL cholesterol), but not others (blood pressure, insulin sensitivity, and serum LDL cholesterol). Moreover, the clinical significance of the favorable changes in the HDL cholesterol–triglyceride axis in the setting of a high fat intake is not clear. Additional, long-term studies are needed to determine whether increased serum HDL cholesterol concentrations and decreased serum triglyceride concentrations have the same effect on cardiovascular outcomes when one is consuming a diet high in saturated fat. It is also possible that the large amount of saturated fats and small amounts of fruits, vegetables, and fiber consumed during the low-carbohydrate diet can independently increase the risk of coronary heart disease.[39,40] Therefore, at the present time, there is not enough information to determine whether the beneficial effects of the Atkins diet outweigh its potential adverse effects on the risk of coronary heart disease in obese persons.

Our study has several limitations. The self-help nature of treatment, which is consistent with the way in which the low-carbohydrate diet is typically used, probably contributed to the attrition rate of 41 percent. This high rate of attrition underscores the difficulty of long-term compliance with either diet, when diet therapy is given with minimal supervision. More comprehensive behavioral treatment (e.g., weekly group meetings or self-monitoring) would probably have decreased attrition, increased adherence, and made possible a comparison with clinic-based treatments for obesity.[23] Our study was focused on weight and specific risk factors for coronary heart disease. We did not evaluate the effect of the low-carbohydrate diet on other important clinical end points, such as renal function, bone health, cardiovascular function, and exercise tolerance. Finally, our findings should not be generalized to overweight subjects or to obese subjects with serious obesity-related diseases, such as diabetes and hypercholesterolemia. Additional studies are needed in these populations to evaluate the safety and efficacy of low-carbohydrate, high-protein, high-fat diets.

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