The Effects of a Low Carbohydrate Diet on
Health Risk Factors, Weight Loss, and Compliance

Health Promotion and Disease Prevention Symposium

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The February 2003 issue of *Men’s Fitness* magazine dubbed St. Louis as the nation’s fifth fattest city, trailing only Houston, Chicago, Detroit, and Philadelphia. The number of overweight and obese people is not only large in St. Louis but is growing throughout the country. Although being overweight or obese used to be considered mostly a cosmetic problem, it has become obvious that weighing too much can cause medical complications. This report aims to consider the efficacy of a low carbohydrate diet on health promotion and weight loss.

We all have images of what it means to be overweight or obese. Clinically speaking, though, a person’s weight classification is based on his or her Body Mass Index, or BMI. Body mass index is calculated as weight in kilograms divided by the square of height in meters ($\text{kg/m}^2$). For an adult, overweight is defined as a BMI greater than or equal to $25.0 \text{ kg/m}^2$ and obese is defined as a BMI greater than or equal to $30.0 \text{ kg/m}^2$.

So how bad of a problem is overweight and obesity in the United States? The most recent data show that the prevalence of obesity in 1999-2000 was 30.5% while the prevalence of overweight during this time period was 64.5%. Thus, almost two thirds of all Americans are now considered to be clinically overweight. These values mark significant increases over the time period from 1988-1994 when the prevalence of obesity was 22.9% and the prevalence of overweight was 55.9% (Flegal 2002). In the early 1960s, fewer than 1 in 4 Americans were classified as overweight or obese (Manson 2003).

The fact that the prevalence of overweight and obesity is increasing in the United States is an important health problem. Excess weight has been shown to be a major risk factor for premature mortality, cardiovascular disease, type 2 diabetes mellitus, osteoarthritis, some types of cancers, and many other medical conditions. Furthermore, almost 300,000 American adults die annually from causes related to obesity. Overweight and obesity is not only a problem for
the individual, though. The United States health care system currently spends about $51.7 billion on overweight and obesity. This accounts for 5.7% of the total United States health expenditure. It is also estimated that overweight and obesity accounts for an additional $47.6 billion of indirect costs to society (http://www.niddk.nih.gov/health/nutrit/pubs/statobes.htm). Together, this means that an almost $100 billion burden is placed on society because of overweight and obesity.

It is therefore reasonable to examine ways to address this tremendous weight problem in the United States. The increased prevalence of overweight and obesity is often accredited to several factors: 1) increased consumption of food ("super-sizing" of meals), 2) greater consumption of high-fat foods, 3) easily available high-calorie, good-tasting, low-cost foods, 4) less active or more sedentary lifestyles (Blackburn 2001). While it has been wellshown that living an active lifestyle, exercising, and monitoring eating habits are helpful in weight loss and weight control, the merits of individual diets are still up for much debate. The rest of this paper investigates the efficacy of a low-carbohydrate diet.

A low-carbohydrate diet may be considered based on several theoretical ideas. First, it has been suggested that high-fat, high-protein, low-carbohydrate diets allow the dieter to feel more satiated after a meal, thus causing the dieter to eat less. Furthermore, more of the foods typical people like to eat will fall into this category making it easier for a dieter to follow his or her plan. These are important considerations since they will most likely increase compliance with the diet, therefore keeping off lost weight. Another theoretical consideration of a low-carbohydrate diet is that such a diet would force the body to switch from carbohydrate metabolism to fat-store metabolism, thus burning accumulated fat and reducing weight. Similarly, such a diet could decrease insulin spikes after meals thus allowing the body to
maintain a catabolic state. Finally, a low-carbohydrate diet would allow the dieter to maintain a proper protein balance despite reduced caloric intake.

Several studies have shown that a diet low in carbohydrates leads to greater weight loss than the standard, higher carbohydrate diet. The analysis of one low carbohydrate diet shows that reducing carbohydrate content to less than 70g and restricting caloric intake without changing protein or fat consumption promotes weight loss. Twenty overweight women underwent 8 weeks of a low carbohydrate diet (50g/day) with energy restriction (reduced by 2644 kJ/day, from 8384 kJ to 5740 kJ) and lost an average of 5 kg and decreased their BMI by 1.8 kg/m². In addition to weight loss, investigators measured BMI, percentage body fat, fasting blood glucose, fasting serum insulin, oral glucose tolerance, free or total IGF, blood pressure, and cholesterol levels. Improvements in body composition, blood pressure, and blood lipids without compromising glucose tolerance in moderately overweight women were observed. The effects of exercise on weight loss or other health factors were not studied. The authors of this study claim that it demonstrates that a low carbohydrate diet is effective for losing weight and for decreasing risk factors for cardiovascular disease; however, this conclusion is problematic for several reasons. The low carbohydrate diet was also a low energy diet, so it is not clear if the benefits are from reduced carbohydrates, or just from reducing the total energy intake of the study participants. In addition, while the total cholesterol and LDL cholesterol had decreased by the end of the 8 weeks, these levels were not significantly different from baseline values obtained before the trial (Meckling 2002).

In an uncontrolled study by Westman et al. on the effects of a low-carbohydrate diet on weight loss and cholesterol levels in men and women also showed weight loss, 66% of which was estimated to be fat mass. Serum bicarbonate levels decreased in patients, but were within
normal levels. Total cholesterol decreased by 11 mg/dL, LDL decreased by 10 mg/dl, and HDL rose by 10 mg/dl. Non-HDL cholesterol decreased by 21, and triglycerides decreased 56 mg/dL over a duration of 24 weeks. The diet composition was 23 +/- 10 g carbohydrates, 115 +/- 29 g protein, 98 +/- 27 g fat, and caloric intake was unrestricted; however, mean daily caloric intake was 1447 +/- 350 kcal. 51% of subjects complied with recommendations to exercise 3 or more times per week on average during the study duration. While this study does demonstrate weight loss with a low-carbohydrate diet, it is difficult to interpret its results in the absence of data from a control group. It is possible that weight loss is due mostly to a decreased caloric intake (despite the design of the study, which does not restrict caloric intake). Further, skin-fold measurements were used rather than more precise techniques (Westman 2002).

The well known and popular Atkins’ diet was studied directly by Larosa et al. for 12 weeks. The researchers identified 24 obese (here, 10% above their maximum weight for height by Metropolitan Life insurance tables) men and women and instructed them to follow the diet described in Dr. Atkins’ Diet Revolution. The normal diet was followed for 2 weeks, and during stage 1, study participants were instructed to consume no carbohydrates but were not given caloric limits. After 4 weeks, stage 2 allowed 5-8 grams of carbohydrates in the diet for 4 more weeks. After this time, the participants were instructed to resume their normal diet for the last 2 weeks of the study. LDL levels showed a significant increase, especially in women. Changes in HDL were not significant. Free fatty acids and uric acid also showed a significant increase in both men and women. Triglycerides were shown to fall significantly in men. The observed weight loss for the combined groups was 7.7 +/- 0.73 kg; however half of the observed total weight loss was during the first two weeks of the beginning of the study diet. These results may be due to the elimination of carbohydrates that ordinarily cause water retention and
unintentionally limiting calories while limiting carbohydrates. Therefore, this diet may be effective for short term weight loss (Larosa 1980).

However, in another study with a longer duration of 6 months, overweight were put on low carbohydrate (35% carbohydrate, 29.9% protein, 35.0% fat) or high carbohydrate (58% carbohydrate, 20.7% protein, 20.5% fat) diets both with 1200 kcals/day hypocaloric intake. Less effect on the difference in weight loss was observed between the two groups than in the previously discussed studies, with the high carbohydrate group losing 4.2 pounds, and the low carbohydrate group losing 5.4 pounds. The BMI of the low carbohydrate group was reduced by 2.2 kg/m$^2$. The differences in all the other measured outcomes including LDL, HDL and triglycerides were not significant. Adherence to each diet showed a 25% dropout rate for both groups. Interestingly, postmenopausal women significantly lost more weight on low carbohydrate diets than those on high carbohydrate diets. This study also did not consider the effects of exercise on weight loss (Lean 1997).

The effects of a high-protein diet ($\geq$25% energy intake) have been compared against other options such as a “balanced” diet, a high-fat diet, or a high-carbohydrate diet. The major health effects to be examined can be grouped into total weight loss, negative health effects, and positive health effects. In order for one to contend that replacing one energy substrate with another will grossly affect weight loss, one must believe that the new substrate is less energy efficient or causes the organism’s behavior to change so that it uses or requires less energy. The proponents of a high-protein diet believe that the thermic effect of feeding (TEF) should cause the body to lose weight. Protein does contribute twice as much to TEF as carbohydrate, though the studies that have examined this topic have found that in the best case scenario one might be able to lose 0.09 kg/month as a result of this strategy. Even though this weight loss difference
was theoretically possible, the studies examined by this group found that no significant weight loss could be attributed to this substitution of energy substrate. As to behavior modification, some studies (as reviewed by Eisenstein et al.) did indicate that there was an increase in satiety from high-protein meals as compared to control meals, though no evidence was presented as to the long-term stability of this effect. The biggest downfall of high protein diets appears to be negative effects on the kidneys. Short-term studies indicate that increased protein intake is associated with increased renal calcium excretion, negative calcium balance, and bone resorption. In addition, one prospective study of >45,000 men age 40-75 showed that intake of animal protein was directly associated with risk of symptomatic kidney stone formation (Eisenstein 2002).

Other studies show that hypocaloric low carbohydrate diets do not result in any differences in weight loss in comparison to hypocaloric high carbohydrate diets. In one 12 week study that followed overweight men and women on low carbohydrate (25% carbohydrate, 30% protein, 45% fat) and high carbohydrate (45% carbohydrate, 29% protein, 26% fat) hypocaloric (<1200 kcal/day) diets showed choice of diet did not influence weight loss or adipose tissue loss after 12 weeks. In addition to weight loss, BMI, LDL, HDL, triglycerides, and diet adherence were measured. Compliance greater than 90% (judging by the weight loss compared to predicted calorie deficit) was observed for both diets. The difference in the loss of lean body mass was not statistically significant between the two groups, and similar improvements in cholesterol, triglycerides, glucose, and glycemia were shown. However, basal insulin fell more markedly in low carbohydrate diet, which may have been because of the higher monounsaturated fat content in the low carbohydrate diet than in the high carbohydrate diet. The exercise level was light to moderate for every patient. Shortcomings of this study are the relatively small
sample size, small proportion of men, and lack of follow-up after 12 weeks. The authors also replaced carbohydrates with fat in the low carbohydrate diet without looking at how varying protein might affect results. Further, authors did not specify whether patients were randomized to the two diets (Golay 1996).

Another hypocaloric diet study was conducted that randomized obese patients in this case to low carbohydrate (15%) or high carbohydrate (45%) diet for 6 weeks with 2 hours of exercise per day. The low carbohydrate diet had higher unsaturated fats compared to the high carbohydrate diet, and protein content similar for each diet. There was no statistically significant difference in percentage weight loss, percentage fat loss, or nitrogen loss between the low carbohydrate and high carbohydrate diets after 6 weeks, and though the drop in fasting plasma glucose, insulin, cholesterol, triglycerides, and HDL cholesterol was smaller in high carbohydrate diet, the differences were not statistically significant. These several studies seem to imply that weight loss is due to hypocaloric diet, not the relative composition of carbohydrates, fats, and protein in the diets (Golay 2000).

Exercise has significant effects on the weight loss and other health factor results of low carbohydrate diets. Since previous studies have shown that low-carbohydrate, high-fat diets lead to an improvement in insulin sensitivity, the effects of a low-carbohydrate, high-fat diet on insulin sensitivity and intracellular glucose processing in healthy, physically fit young men without family histories of diabetes was studied over three weeks. The men were instructed to continue their exercise regimens, and the group included 1 triathlete, 3 long-distance bicyclists, 4 runners, 2 runners/weight lifters. The low carbohydrate diet (8% carbohydrate, 17% protein, 75% fat) was compared to the standard diet (51% carbohydrate, 14% protein, 35% fat), both with normal caloric intake of approximately 3500 kcal/day. It was shown that the low carbohydrate
diet caused a drop in mean fasting serum insulin levels from 36+/−6 to 12+/−2 pmol/L. However, the mean fasting plasma glucose concentration was unchanged. Although the rate of disappearance of glucose was not affected, substantial alterations in the routes of intracellular glucose metabolism were seen. Glucose oxidation dropped under both basal conditions and insulin infusion, while nonoxidative glucose metabolism increased. On the low carbohydrate diet, insulin had a decreased ability to decrease net fat oxidation; however, free fatty acid levels were promptly suppressed by insulin infusion on both diets. Myocyte PDH (pyruvate dehydrogenase) activity decreased dramatically on low-carbohydrate diet. Insulin-stimulated glycogen synthase activation was much greater during the low carbohydrate diet. These results show that aerobic capacity is important in maintaining insulin-stimulated nonoxidative glucose metabolism during a low carbohydrate diet. Further, in young, physically fit subjects, the eucaloric substitution of fat for carbohydrates does not uniformly lead to a decrease in overall insulin sensitivity. In normal individuals, physical conditioning and dietary composition interact in modulating carbohydrate metabolism (Cutler 1995).

In another study, 23 obese women were randomly assigned to aerobic exercise or no exercise and to energy restricted low fat (60% carbohydrate, 25% protein, 15% fat) or low carbohydrate (25% carbohydrate, 25% protein, 50% fat) diets both with reduced caloric intake (1200 kcal/day for non-exercising group) for 12 weeks. Prescribed intakes for subjects assigned to the exercise groups were increased to compensate for the calculated energy costs of the exercise sessions. Exercise was found to increase loss of fat tissue as opposed to fat-free tissue (muscle, bone, etc.). Aerobic exercise significantly enhanced fat loss by 2.7 kg. Slightly higher weight loss was observed with low carbohydrate compared to low fat diet (10.6 kg vs. 8.1 kg) but no difference in body composition was seen. It can be suggested that the decrease in the rate
of weight loss with time found in low-energy diets is because of losses of fat-free body mass, which could cause reductions in resting metabolism, decreases in postprandial energy expenditure because of smaller meals, and decreases in the energy cost of movement because of smaller body size (Racette 1995).

Some studies have shown that the difficulty of complying with the low carbohydrate diet may reduce the theoretical effectiveness of the diets in practice. Landers et al. describes a study done on 91 obese patients between the ages of 18 and 55. Each patient was randomly assigned to one of three dieting groups: low carbohydrate, high protein diet (less than 30g carbohydrate per day); The Zone Diet (snack of 40% carbohydrate, 30% protein, 30% fat five times a day); a conventional diet (reduced calories, 50% carbohydrate, 20% protein, 30% fat). These diets allow the energy needed to promote weight loss of .45 kg/week. The observed mean weight loss after 12 weeks of dieting was 5.2 kg. There were no significant differences between the different dieting groups. It is difficult to analyze the results of the study due to the high patient drop out (49 out of 91 original subjects completed the study), and due to poor diet compliance among the participants. Following completion of the study, no dieters from the low carbohydrate or high protein group continued with their diets. Zone dieters generally liked their diet. Conventional plan dieters felt the experimental diet closely approximated a well-balanced eating plan that would promote healthy eating habits. In light of these results, the researches recommend that weight loss instructions be kept simple for patients (Landers 2002).

While a number of studies have attempted to study the effects of a low-carbohydrate diet on weight loss and other parameters of health, there are many difficulties in drawing definitive conclusions from these studies. The duration of most studies ranged from several weeks to up to six months, with little or no long term follow up. Thus, we are left with little information on
long-term diet adherence, weight loss, cardiovascular health, insulin tolerance, etc. All the same, some conclusions can be drawn by examining several parameters in combination – body weight lost, metabolic parameters, body composition, nutritional adequacy, and compliance.

It seems that a hypocaloric diet, regardless of its nutritional breakdown, will result in weight loss, since it is really the reduction of calories consumed that drives weight loss. The obvious plan for weight loss, then, would be simply to eat less. The difficulty is in convincing Americans to eat less and to continue to eat less on a permanent basis.

Numerous studies have shown that high-fat and high-carbohydrate diets can cause cardiovascular disease and diabetes, respectively, as well as a variety of other health problems. In low carbohydrate diets, the calories tend to be replaced by proteins, which as discussed above, can lead to negative effects on the kidneys. Nevertheless, it seems that all forms of weight loss, regardless of the approach taken, lower blood lipid levels, improve glycemic control, and lower blood pressure (Freedman 2001).

When losing weight, body composition is important to consider because ideally, one would lose body fat, rather than lean body mass or some other component. High-fat, low-carbohydrate ketogenic diets cause a greater loss of body water than body fat at first, resulting in the regaining of water weight when the diet ends. In the long run, though, all diets result in the loss of body fat.

Another important factor to look at in choosing a diet is whether or not the restrictions allow for balanced, nutritionally-adequate meals. High-fat, low-carbohydrate diets are low in vitamins E, A, thiamin, B₆, folate, calcium, magnesium, iron, potassium, and dietary fiber, and thus require supplementation. Very low fat diets are also nutritionally inadequate, since they are low in vitamins E, B₁₂, and zinc.
Finally, the issue of compliance is perhaps the most important, since no diet will be effective unless people are willing to follow it. As brought up in the study by Landers et al, a diet with simple guidelines seems to be the easiest for patients to follow. In this respect, a conventional diet with balanced food groups might be the easiest to maintain. Another major complaint is that diets which cut calories leave one feeling hungry all the time. Diets high in protein and fat appear to lead to greater satiety, which could lead to better compliance.

Obviously, there is no simple answer as to which diet is the best. Each diet has advantages and disadvantages, as well as components that have not yet been adequately research to draw definitive conclusions about. Perhaps the best recommendation, then, is for patients to choose their diet on a case by case basis. A patient who complains of feeling hungry all the time on conventional foods may benefit from a high-protein diet such as the Atkins diet; a patient with little time to prepare special foods, however, may be best off with a balanced, low-fat diet. Patients with kidney disease or osteoporosis may want to avoid high protein diets, and patients with cardiovascular disease may want to avoid substituting fats for carbohydrates. Of course, there may be other positive and or negative health effects to distinguish the various diets that are not yet apparent. Finally, there are behavioral factors that are important for all diets regardless of the nutritional breakdown, such as exercise and behavioral modifications, including self-weighing. In the end, all diets seem to boil down to calorie restriction, so personal factors may outweigh any other advantages or disadvantages in maintaining a successful diet.
References


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Defining Obesity

- BMI is kg/m²
  - Normal is between 18 and 24.
  - Overweight is 25 kg/m² or greater.
  - Obese is 30 kg/m² or greater.

- Major increase in obesity over the past 40 years
  - 1960’s <25% obese or overweight
  - 2000 64.5% are obese or overweight
Why do we care?

- Co-morbidity
- Cost
- Clinical Obstacles
Dieting

- Fad diets
- Weight loss programs
- “Clinically proven” popular diets
  - Atkins Diet
  - Zone Diet
Investigating Obesity

- BMI
- Body Fat %
- Fasting blood glucose
- Serum insulin
- Oral glucose tolerance
- Free and total IGF
- BP
- Cholesterol (lipid profile: HDL/LDL)
- Compliance
Study Design

- Duration
- Patient Population
- Follow-up
  - Exercise
  - Control
  - Total Calories
Compliance

- Restricted diet \(\rightarrow\) Drop-outs
- Exercise regimens
- Inpatient vs. Outpatient studies
Problems with Studies

- Controlled vs. Un-controlled
- Comparison
- Compliance and enrollment
- Methods and measurements
- Sample size
- Duration of study
So, what about Atkins?

Study Design:

- Weeks 1-2: normal diet
- Weeks 3-6: no CHOs, no caloric limit in other categories
- Weeks 7-9: limit 5-8 grams of CHOs per day, no limits in other categories
- Weeks 10-12: resume normal diet
Results

- LDL levels increased significantly, HDL levels did not change significantly.
- FFAs increased significantly.
- Triglycerides fell significantly in men.
- Observed weight loss: 16.94 +/- 1.61 lbs, approximately half of this weight loss occurred during the initial 2 weeks.
Problems with study

- Small sample size
- Incomplete measurement of endpoints
- Weight loss attributed to?
- Short follow-up
- Compliance
Authors’ favorite diet:

- Random Assignment
- Compare 3 groups:
  - Low calorie (unrestricted content)
  - low carb/ high protein and fat
  - low fat/ high carb and protein
- Large sample size
- Journal
- Monitor compliance
  - plasma glucose
  - urine nitrogen
Conclusion

- Weight loss: caloric output > caloric intake
- No agreement on “the best” diet
  - Low carb diets → satiation with low calorie intake (Eisenstein et al, 2002)
- Diet must be tailored to each patient