Types of Carbohydrates and Risk of Cardiovascular Disease

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ABSTRACT

The purpose of this review is to provide an overview of the role of dietary carbohydrates in the etiology of cardiovascular disease (CVD) among women. Many factors are thought to affect insulin resistance, and little is known about the role of diet. Through effects on postprandial glucose and insulin, dietary glycemic load may have an important role in the insulin resistance syndrome (IRS). Dietary fiber, through its influence on the glycemic load or through other pathways, may also have important effects on this syndrome. Many short-term experimental studies have supported these hypotheses. Interestingly, associations may be stronger among overweight individuals than among nonoverweight individuals. Similar to findings for fruits and vegetables, whole grain intake has been found to be consistently associated with a reduction in risk of coronary heart disease (CHD) among both men and women. Several large randomized trials of primary and secondary prevention to date have demonstrated the efficacy of diets based on an abundance of plant foods and, therefore, high carbohydrate quality. The recommendations to follow a diet including an abundance of fiber-rich foods in order to prevent CVD and diabetes are based on a wealth of consistent scientific evidence. More long-term controlled trials are needed to improve our understanding of efficacy and mechanisms. Women and a variety of racial/ethnic groups should be represented in these studies whenever possible.

INTRODUCTION

The purpose of this paper is to provide an overview of the role of dietary carbohydrates in the etiology of cardiovascular disease (CVD) among women. The initial sections provide historical perspectives, with particular insight into some intriguing ecologic perspectives of dietary trends and the recent epidemic of obesity and type 2 diabetes. Specific types of dietary carbohydrates are defined and discussed in light of their relevance to the pathogenesis of CVD. Cross-sectional and prospective epidemiologic studies are reviewed in detail, and the pertinent randomized clinical trials on this topic also are considered. Finally, future research directions and public health implications are offered.

HISTORY AND TRENDS IN CARBOHYDRATE INTAKE

Historically, humans evolved on a diet of protein and fat and limited in carbohydrates. It was not until the agricultural revolution of 10,000 years ago that carbohydrate intake became a main component of the diet. An additional increase of carbohydrate in the food supply, as well as a de-
crease in carbohydrate quality, followed the industrial revolution about 100 years ago. Over the past 30 years, there has been a further increase in percentage of energy in the diet coming from carbohydrate, at least in the United States and other developed nations. This increase in carbohydrate intake appears to be of particular concern because of the rising rates of obesity over this same period.

CLASSIFICATION OF DIETARY CARBOHYDRATES

Since the early 1900s, carbohydrates have been classified according to chain length. In 1977, official recognition was given to the distinction between simple sugar and complex carbohydrate by the McGovern Commission. In the 1990s, the Food Guide Pyramid placed grain-derived starchy foods at the base and sugar at the top—a clear emphasis on complex carbohydrates as part of a healthy diet. However, studies that have demonstrated similar effects of simple and complex carbohydrates on the blood glucose response can call into question the rationale for classifying carbohydrates solely on their chemical chain length. In the early 1980s, the glycemic index (GI) was developed as a physiologic basis for classifying carbohydrates. The GI is defined as the area under the blood glucose curve following consumption of 50 g of available carbohydrate from some test food relative to the area under the curve (AUC) following consumption of 50 g of available carbohydrate from a reference food, either pure glucose or white bread. Factors that affect GI are food form, structure, type of sugar, starch, fiber, and processing and cooking method. Dietary glycemic load (GL) is a physiologic measure of the overall effects of dietary patterns on blood glucose and insulin. GL is computed as the product of the diet and the GI for each food in the diet and the grams of available carbohydrate provided by the specific amount of that food that was consumed.

The first international tables of the GI were published in the American Journal of Clinical Nutrition in 1995. The updated tables have just been published in 2002, and they include estimates for the GL of hundreds of foods. Fiber, in particular, may have effects on physiology and health through the GI or independent of the GI, such as through binding of bile acids and lowering of low-density lipoprotein (LDL) cholesterol or effects on blood pressure and insulin sensitivity. Therefore, we consider GL and dietary fiber as the critical components that can be used to evaluate the quality of dietary carbohydrate. Table 1 provides an overview of the GI and fiber content of the common sources of carbohydrate in the diet.

Dietary Sources of Carbohydrate in the U.S. Population

Prevalence estimates from a 1994–1996 United States Department of Agriculture (USDA) survey indicated that only 3% of the population was consuming ≥3 servings of vegetables with ≥1 of 3 dark green or orange, and only 7% were consuming ≥2 servings of fruit per day. Table 1 provides an overview of the GI and fiber content of the common sources of carbohydrate in the diet.
sumption ≥6 daily servings of grains with ≥3 whole grain.\textsuperscript{11} Furthermore, soda intake has increased precipitously in adolescents, and milk intake has declined considerably over the past 30 years in this age group.\textsuperscript{12} Therefore, it appears that the prevailing dietary pattern of the United States in the late 20th and early 21st century is one that includes mostly white bread, white rice, pasta, potatoes, soda, and snacks. These foods are commonly eaten in fast food restaurants or otherwise preprepared and packaged so that they are economical and easily consumed.

### PATHOGENESIS OF THE INSULIN RESISTANCE SYNDROME: ROLE OF DIETARY CARBOHYDRATE

As shown in Figure 1, insulin resistance and obesity are tightly linked and contribute to a clustering of risk factors for type 2 diabetes and CVD, the so-called insulin resistance syndrome (IRS), including glucose intolerance, low high-density lipoprotein (HDL) cholesterol, high triglycerides, elevated blood pressure, prothrombotic potential, and systemic inflammation.\textsuperscript{13} The prevalence and incidence of IRS have been found to be extraordinarily high among U.S. adults. Recent data from the third National Health and Nutrition Examination Survey (NHANES III) estimate that nearly 1 in 4 U.S. adults have IRS.\textsuperscript{14} The prevalence is considerably higher for Mexican American women (36%) and for adults >40 years of age (≥40%).\textsuperscript{14} Furthermore, the 10-year cumulative incidence of IRS was recently documented among young African American and Caucasian men and women in the Coronary Artery Risk Development in Young Adults (CARDIA) Study.\textsuperscript{15} Among those who were overweight at the start of the study, 41% of African American men and women and 33% of Caucasian men and women developed IRS over 10 years.\textsuperscript{15}

Although many factors are thought to affect insulin resistance, little is known about the role of diet. Through effects on postprandial glucose and insulin, dietary GL may have an important role in this syndrome.\textsuperscript{16} Dietary fiber, through its influence on the GL or through other pathways, may also have important effects on the IRS.\textsuperscript{17} Many short-term experimental studies have supported these hypotheses.\textsuperscript{7,9,17,18}

### EPIDEMIOLOGIC COHORT STUDIES OF CARBOHYDRATES AND CVD

Disease biomarkers

Several cross-sectional studies have examined dietary GL in relation to biomarkers of CVD. Among young African American and Caucasian adults of the CARDIA Study, whole grain consumption was inversely associated with fasting

**FIG. 1.** The insulin resistance syndrome. Type 2 diabetes and CVD share common antecedents.
insulin levels in a cross-sectional analysis. Recently, the Framingham Offspring Study also reported an inverse dose-response association between whole grain intake and fasting insulin. To determine causality, a feeding study compared two step-1 diets comprising either whole or refined grain and found improved insulin sensitivity on the whole grain diet compared with the refined grain diet. Recent cross-sectional epidemiologic cohort studies of dietary GL and HDL cholesterol, triglycerides, and C-reactive protein (CRP) have found graded dose-response associations, independent of body weight and other lifestyle and dietary factors. Interestingly, associations may be stronger among overweight individuals than among nonoverweight individuals. Such an interaction between body weight and GL would be biologically plausible because overweight people are more resistant than nonoverweight people to insulin and at higher risk of subclinical and overt type 2 diabetes and CVD. Therefore, the adverse effect of a high-GL diet may be more pronounced among overweight individuals.

Obesity

Many cross-sectional studies have found that intake of whole grains, fruits, and vegetables is inversely associated with body mass index (BMI). However, little is known about the possible effects of these food groups on weight gain and risk of obesity in prospective studies. In the CARDIA Study, macronutrient and fiber intake was examined in relation to 10-year weight gain. Fiber, but not dietary fat, demonstrated strong associations with weight gain. After adjustment for other dietary and lifestyle factors, those in the lowest quintile of fiber intake (<5 g/1000 kcal/day) gained 8 more pounds, on average, than those in the highest quintile (>12 g/1000 kcal/day). This association was consistent within each tertile of dietary fat intake, suggesting that the effect of fiber was not explained by intake of dietary fat. Also from the CARDIA Study, dairy products, a very low GL food group, were examined recently in relation to the development of the IRS over 10 years. Among those who were overweight at the start of the study, consuming dairy products at least 5 times per day was associated with a 72% reduction in the odds (95% confidence interval [CI], 42% to 86%, p < 0.001) of developing the IRS over the 10-year period compared with those consuming dairy products <2 times per day. No association was noted among those who were not overweight at the start of the study, consistent with findings of previously described studies for interactions between BMI and GL. Those consuming intermediate amounts of dairy products had intermediate odds of developing the IRS. Each daily eating occasion of dairy products was associated with a 20% reduction in odds of developing the IRS. This association was consistent for all components of the IRS, with the exception of HDL cholesterol, including obesity, high blood glucose or insulin, elevated blood pressure, and triglycerides. The association was also consistent for all types of dairy products, regardless of fat content, with the exception of butter and cream, for which there was no association. As fiber was also found to have a strong inverse association with the odds of developing the IRS, it was important to examine the joint associations of both dairy products and fiber. In fact, the associations of dairy products and fiber with the IRS were clearly independent and additive. Those in the lowest tertiles of consumption of both dairy products and fiber were seven times more likely to develop the IRS over the 10-year periods than those in the lowest tertile of consumption of each of these two dietary factors (Fig. 1.).

Disease incidence

There is consistent evidence from prospective cohort studies that fruits, vegetables, and whole grains, sources of high-quality carbohydrate, reduce the risk of CVD. Recent studies of fruit and vegetable consumption, or carotenoid intake as a marker of fruit and vegetable consumption, are described in Table 2. In women and men from the United States and Finland, relatively high fruit and vegetable intake is associated with a reduction in risk of CVD on the order of 25%–55% compared with those consuming low amounts of these foods. These findings are consistent for women and men and for different CVD end points, including myocardial infarction (MI) and stroke. The findings are also independent of other lifestyle and dietary factors, including BMI. Figure 2 summarizes findings from cohort studies on whole grain or cereal fiber as a marker of whole grain intake and the risk of developing coronary heart disease (CAD). Similar to findings for fruits and vegetables, whole grain intake has
been found to be consistently associated with a reduction in risk of CHD among both men and women.32–37 The facts that these associations behave in a dose-response manner and that these studies have controlled for other dietary and lifestyle factors, including BMI, provide important information supporting the hypothesis that whole grain foods, through their fiber, antioxidants, and other components, reduce the risk of CHD in a causal manner.

Fewer epidemiologic studies have been conducted on the GL, probably because it is a relatively new and controversial dietary factor. Many of the existing epidemiologic studies do not have the dietary glycemic index (GI) available in their databases. The GL risk of coronary disease has been evaluated in only one study. Among women in the Nurses’ Health Study with a BMI of at least 23, there was a strong positive association between the GL and risk of CHD.38

TABLE 2. COHORT STUDIES OF FRUIT AND VEGETABLE INTAKE AND RISK OF CVD

<table>
<thead>
<tr>
<th>Study</th>
<th>Dietary assessment</th>
<th>End point</th>
<th>Relative risk comparing high vs. low intake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaziano et al., 199526</td>
<td>1,273 adults aged 65+</td>
<td>FFQ, carotenoids</td>
<td>CVD death</td>
</tr>
<tr>
<td>Knekt et al., 199427</td>
<td>5,133 adults</td>
<td>Diet history, vegetables</td>
<td>CHD death</td>
</tr>
<tr>
<td>Joshipura et al., 199628</td>
<td>75,966 women 14-year duration 38,683 men</td>
<td>FFQ, fruits/veg</td>
<td>Ischemic stroke</td>
</tr>
<tr>
<td>Joshipura et al., 200129</td>
<td>84,251 women 14-year duration 42,148 men</td>
<td>FFQ, fruits/veg</td>
<td>CHD</td>
</tr>
<tr>
<td>Liu et al., 200030</td>
<td>39,127 women 5-year duration</td>
<td>FFQ, fruits/veg</td>
<td>Stroke, MI, or CVD</td>
</tr>
<tr>
<td>Liu et al., 200131</td>
<td>15,520 men (12 y) 12-year duration</td>
<td>FFQ, Carotenoids/veg</td>
<td>CHD</td>
</tr>
</tbody>
</table>

FFQ = Food Frequency Questionnaire.

FIG. 2. Relative risk of CHD by cereal fiber or whole grain intake in prospective studies, adjusted for BMI, lifestyle, and dietary factors.
Nurses’ Health Study and in the Health Professionals Follow-up Study, the dietary GL has been found to be a very important determinant of type 2 diabetes. A particularly interesting analysis from these studies was that the dietary GL and the intake of cereal fiber were independent and additive in their association with risk of type 2 diabetes. Those nurses with a high GL diet and a low intake of cereal fiber (e.g., high potato and white bread intake and low intake of leafy green vegetables) had a risk of type 2 diabetes that was 2.5 times higher than that of women with low GL and high cereal fiber intake. One particular advantage of these large prospective cohort studies is the repeated dietary assessments over many years, which enables the researchers to update diet by taking the average of several food frequency questionnaires over time. Such averaging should reduce the random component of measurement error in dietary estimation, an important methodologic issue in nutritional epidemiology. In the Iowa Women’s Health Study, there was no association observed between dietary GL and the risk of type 2 diabetes, perhaps because this study only has one baseline food frequency questionnaire.

RANDOMIZED TRIALS

Several large randomized trials of primary and secondary prevention have demonstrated the efficacy of diets based on an abundance of plant foods and, therefore, high carbohydrate quality. In the Da Qing Trials, 577 people with impaired glucose tolerance who were randomized to a diet rich in vegetables over 6 years of follow-up had a 24% lower incidence of type 2 diabetes than controls. Among 459 adults in the Dietary Approach to Stop Hypertension (DASH) study, significantly lower systolic and diastolic blood pressure was observed on a low-fat diet rich in dairy products, fruits, and vegetables over 3 weeks. In the Lyon Diet Heart Study, 605 MI survivors who followed a fruit and vegetable diet for 2 years had a 46% lower risk of recurrent MI compared with controls. In each of these studies, it is not clear if the dietary GL was an important component of the diets, contributing to their efficacy. Also, the role of dietary fiber and whole grains and the relative proportions of carbohydrate and fat are in need of further study.

CONCLUSIONS AND DIRECTIONS FOR FUTURE RESEARCH

Whole grains, fruits, and vegetables and an overall low GL diet appear to reduce the risk of CVD and type 2 diabetes in men and women of all ages. Dietary approaches to risk reduction may be particularly effective among the most susceptible individuals—those who are overweight and insulin resistant. The recommendation to follow a diet that includes an abundance of fiber-rich foods in order to prevent CVD and diabetes is based on a wealth of consistent scientific evidence. Areas in particular need of further study include dietary composition and obesity, dairy products and risk of obesity, CVD, diabetes, and cancer. More long-term controlled trials are needed to improve our understanding of efficacy and mechanisms. Women and a variety of racial/ethnic groups should be represented in these studies whenever possible.

REFERENCES

CARBOHYDRATES AND CARDIOVASCULAR DISEASE


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