

# Diet, Lifestyle, and the Etiology of Coronary Artery Disease: The Cornell China Study

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Investigators collected and analyzed mortality data for >50 diseases, including 7 different cancers, from 65 counties and 130 villages in rural mainland China. Blood, urine, food samples, and detailed dietary data were collected from 50 adults in each village and analyzed for a variety of nutritional, viral, hormonal, and toxic chemical factors. In rural China, fat intake was less than half that in the United States, and fiber intake was 3 times higher. Animal protein intake was very low, only about 10% of the US intake. Mean serum total cholesterol was 127 mg/dL in rural China versus 203 mg/dL for adults aged 20–74 years in the United States. Coronary artery disease mortality was 16.7-fold greater for US men and 5.6-fold greater for US women than for their Chinese counterparts. The combined coronary ar-

tery disease mortality rates for both genders in rural China were inversely associated with the frequency of intake of green vegetables and plasma erythrocyte monounsaturated fatty acids, but positively associated with a combined index of salt intake plus urinary sodium and plasma apolipoprotein B. These apolipoproteins, in turn, are positively associated with animal protein intake and the frequency of meat intake and inversely associated with plant protein, legume, and light-colored vegetable intake. Rates of other diseases were also correlated with dietary factors. There was no evidence of a threshold beyond which further benefits did not accrue with increasing proportions of plant-based foods in the diet. ©1998 by Excerpta Medica, Inc.

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**C**oronary artery disease is a complex biologic phenomenon. Its cause, progression, and treatment should not be oversimplified. Research and public health policies that focus on single agents, single events, single outcomes, and linear relations will be unsuccessful. We need to understand the complex natural history of coronary artery disease, but we also need to consider the possibility that there is a simple solution to this disease.

It was this view that led researchers to launch a comprehensive nationwide investigation of diet, lifestyle, and disease mortality in populations in rural mainland China, and then later in Taiwan. With the results, we have been able to describe practical relations between possible disease cause and disease occurrence. This article summarizes selected findings from the first of 2 studies, China Study I,<sup>1,2</sup> which includes data from surveys of dietary and lifestyle factors as well as disease mortality.

In China Study I, investigators collected and analyzed mortality data for >50 diseases, including 7 different cancers, from 65 counties and 130 villages. Samples of blood, urine, and food were collected from 50 adults in each village and were analyzed for a variety of nutritional, viral, hormonal, and toxic chemical factors. Concurrently, extensive and detailed di-

etary data were collected from the study participants and the results entered into computer storage. A total of 367 dietary, lifestyle, and disease characteristics judged to be reliable were published both in English and Chinese in a 900-page monograph in 1990.<sup>3</sup>

Data are now being compiled for China Study II, a survey conducted 1989–1990, of diet and lifestyle in 170 villages in both mainland China and Taiwan, combined with updated, more extensive disease mortality data (including 100 million people and >100 disease rates) from 1986–1988. We anticipate publication in 1999.

## DIETARY CHARACTERISTICS: CHINA VERSUS THE UNITED STATES

Diets in rural China, 1983–1984, were vastly different from those in the United States (Table I). Fat intake in China was less than half of that of the US fat intake in terms of percentage of total calories, and fiber intake was 3 times higher in the rural Chinese diet than the US diet on the basis of grams per day. Intake of animal protein was very low in rural China, only about 10% of the US diet, expressed as a percentage of dietary calories. This substantial difference in animal protein intake indicated major differences in many other dietary and metabolic characteristics as well. For example, blood cholesterol, with a mean of 127 mg/dL, was substantially lower in rural China than in the United States, where the mean cholesterol level for adults aged 20–74 years was 203 mg/dL.

Energy (calorie) intake per kg of body weight is about 30% higher in China than in the United States, yet the prevalence of obesity was much lower in China. Mean body mass index in rural China, for example, was 20.5, compared with 25.8 in the United States. This observation is remarkable because Chi-

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nese energy intake (of adult males) was standardized for a hypothetical reference person, a male office worker involved in the least amount of physical activity. The average Chinese office worker, therefore, is apparently consuming more energy but is much less inclined toward obesity than the average US citizen engaged in any manner of work. However, Chinese office workers are more active than US office workers, because the Chinese generally bicycle to work each day. Thus, their high energy intake is likely to be attributable to increased energy expenditure.

## DIET-DISEASE RELATIONS

The principal hypothesis of this study was that the greater the dietary proportion of a variety of good-quality plant-based foods, the lower the rate of chronic degenerative diseases. We used 2 strategies to interpret the data we gathered to test this hypothesis: (1) we attempted to determine whether groups of diseases share common etiologies; and (2) we examined specific cause- and effect hypotheses.

The first strategy demonstrated that certain diseases were indeed associated and fell into 2 geographically localized groups, identified as group A and group B (Table II). Each disease is positively associated with diseases in its own group but inversely associated with diseases in the other group.<sup>4</sup> Diseases in group A are characteristic of developing countries, like China, whereas those in group B are characteristic of Western countries, like the United States. Such geographic aggregations of diseases suggest that each disease group tends to have its own set of common dietary and lifestyle causes.

A broad selection of variables, possibly representing such common causes, were investigated. The variables chiefly associated with group B, or Western, diseases were total blood cholesterol and blood urea nitrogen (Figure 1). Blood urea nitrogen was associated mainly with intake of meat, milk, and eggs. Blood cholesterol was directly associated with consumption of dietary fat, animal protein, and meat and inversely associated with intake of dietary fiber and legumes (Figure 2).<sup>5</sup> Group B (Western) diseases have often been called diseases of affluence, but we suggest that a more meaningful description might be diseases of nutritional extravagance.

The second investigative strategy revealed several relations.

- Breast cancer mortality increases with increasing dietary fat concentration and blood cholesterol levels.<sup>6</sup> Nutritionally rich diets increase childhood growth rates, causing menarche at an earlier age, a phenomenon that has been associated with higher risk of breast cancer later in life. These findings suggest that the fastest rate of childhood growth may not be the healthiest, either for Chinese or for Westerners.

- Body height attained by adults was positively associated with intake of plant protein. This observation supports the view that the genetic potential for adult body height can be attained simply by consuming adequate amounts of an appropriate variety of plant-based foods. Childhood growth rates increased steadily in rural

**TABLE I** Comparison of Diets in the United States and China (1983–1984)

	United States (2,360 Kcal)*	China (2,630 Kcal)*
Fat (%)	36	14
Carbohydrate (%)	42	71
Alcohol (%)	7	5
Fiber (g/day)	11	33
Protein (%)	15 <sup>†</sup>	10 <sup>‡</sup>
Animal protein (%)	~10	~1

\*Equivalent of 30.6 Kcal/kg and 40.6 Kcal/kg body weight, respectively.

<sup>†</sup>70% of protein calories are from animal sources.

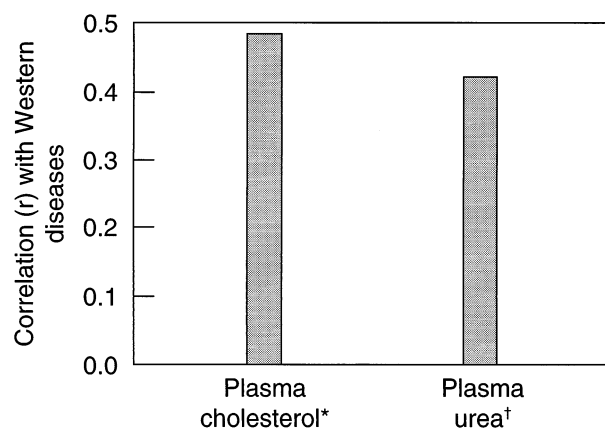
<sup>‡</sup>11% of protein calories are from animal sources.

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**TABLE II** Consistently Correlated Disease Groups

Group A (More Typical of Developing Countries)	Group B (More Typical of Western Countries)
Pneumonia	Colon cancer
Intestinal obstruction	Lung cancer
Peptic ulcer	Breast cancer
Digestive diseases	Leukemia
Nephritis	Diabetes
Pulmonary tuberculosis (TB)	Coronary disease
Non-TB infectious diseases	Brain cancer (0–14 years)
Parasitic diseases	Stomach cancer
Eclampsia	Liver cancer
Rheumatic heart disease	
Metabolic and endocrine disease other than diabetes	
Diseases of pregnancy and birth other than eclampsia	

Adapted from *Ecol Food Nutr*.<sup>4</sup>



**FIGURE 1.** Correlates of diseases of nutritional extravagance. \* Plasma urea nitrogen correlated with intake of milk (2-tailed)  $2p < 0.01$ ; † Plasma urea nitrogen correlated with intake of meat and eggs,  $2p < 0.001$ . (Adapted with permission from *Ecol Food Nutr*.<sup>4</sup>)

China between 1950 and 1980, when the average diet contained only 10–12% fat content, and 3–6% animal-based foods (Figure 3).<sup>7</sup> The improvements in childhood

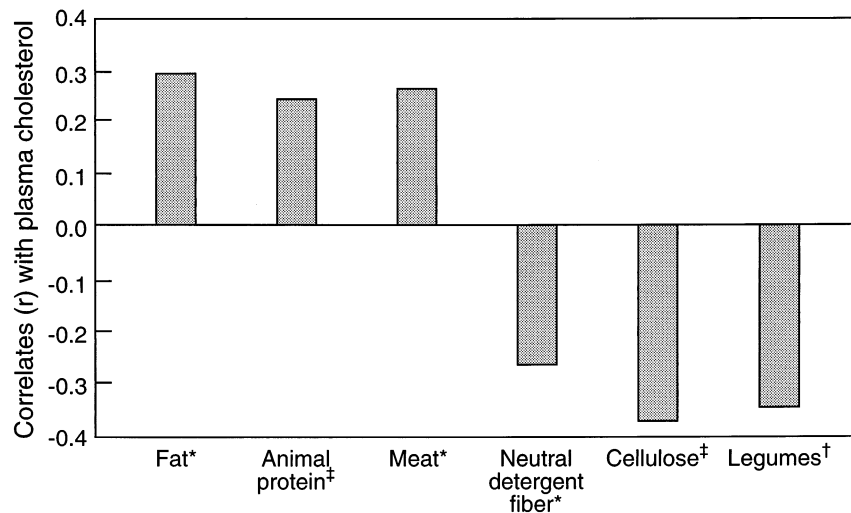


FIGURE 2. Dietary correlations with plasma cholesterol. \*  $2p < 0.05$ ; †  $2p < 0.06$ ; ‡  $2p < 0.01$ . (Adapted from *Cancer Res.*<sup>5</sup>)

growth rates occurred about as rapidly as was observed in Japan after World War II.

- Higher blood levels of vitamin C and beta carotene are associated with lower rates of several cancers.<sup>8,9</sup> These disease-inhibiting antioxidant vitamins are provided almost entirely by plant-based foods.

## DIET-CORONARY ARTERY DISEASE RELATIONS

We also examined the association of coronary artery disease with diet.<sup>3</sup> The relative mortality rates for coronary artery disease in rural China and the United States are strikingly different. Coronary mortality rates in China observed during 1973–1975 in this ecologic, cross-sectional study, truncated for ages 0–64 years, are 4.0 per 100,000 for men and 3.4 for women,<sup>3</sup> compared with 66.8 per 100,000 men and 18.9 per 100,000 women in the United States.<sup>10</sup> These

figures represent remarkable 16.7-fold and 5.6-fold greater mortality rates among US men and women, respectively, than among their Chinese counterparts. Even more remarkable were the extraordinarily low rates observed in the southwestern Chinese provinces of Sichuan and Guizhou. The lowest rates for males occurred in a Guizhou county, where there were *no* recorded coronary artery disease deaths for males  $\leq 64$  years of age among a population of 246,000 males during a 3-year observation period (1973–1975). A county in nearby Sichuan province had the lowest rates for females, with no coronary artery disease deaths recorded for females  $\leq 64$  years of age during the observation period among a population of 181,000 females.

The combined coronary artery disease mortality rates for both genders in rural China were inversely associated with the frequency of intake of green vegetables ( $r = -0.43$ ,  $p < 0.01$ ) and plasma erythrocyte monounsaturated fatty acids ( $r = 0.64$ ,  $p < 0.001$ ), but positively associated with a combined index of salt intake plus urinary sodium ( $r = 0.42$ ,  $p < 0.01$ ) and plasma apolipoprotein B ( $r = 0.37$ ,  $p < 0.01$ ). These apolipoproteins, in turn, are positively associated with animal protein intake ( $r = 0.26$ ,  $p < 0.05$ ) and the frequency of meat intake ( $r = 0.32$ ,  $p < 0.01$ ) and inversely associated with plant protein ( $r = 0.37$ ,  $p < 0.01$ ), legume ( $r = 0.26$ ,  $p < 0.05$ ), and light-colored vegetable intake ( $r = 0.25$ ,  $p < 0.05$ ).

The similarity between these associations and those observed for Westerners, who generally have much higher plasma cholesterol concentrations, suggests a linear relation between the consumption of foods of animal origin and coronary artery disease mortality all the way to the virtual exclusion of these foods from the diet.

Among the  $> 8,000$  statistically significant (at  $p < 0.05$ ) correlations we made, a few appear to remain at odds with the impressive ones noted above. For example, we found coronary artery disease to be

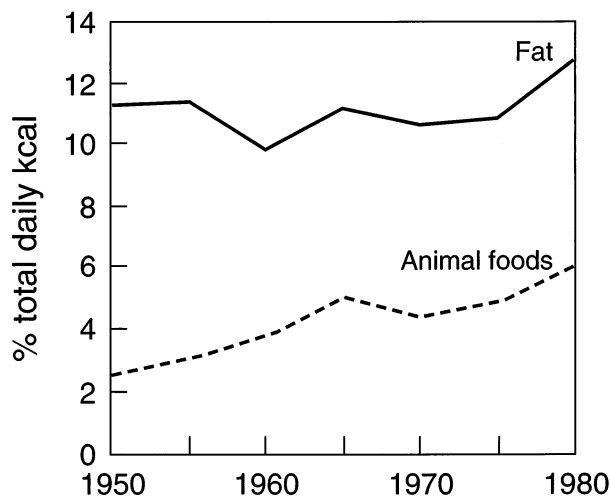


FIGURE 3. Chinese food and nutrient trends, 1950–1980. (Adapted from *Food Consumption and Nutritional Status in the People's Republic of China.*<sup>7</sup>)

associated with wheat flour intake ( $r = 0.67$ ,  $p < 0.001$ ). Compared with populations that do not consume wheat flour, however, those that do also consume more milk ( $r = 0.27$ ,  $p < 0.05$ ) and salt ( $r = 0.34$ ,  $p < 0.01$ ), and have higher circulating levels of plasma triglycerides ( $r = 0.51$ ,  $p < 0.01$ ), greater adult weight ( $r = 0.59$ ,  $p < 0.001$ ), and less frequent consumption of green vegetables ( $r = -0.63$ ,  $p < 0.001$ ). These factors may explain the association. Nevertheless, the wheat-flour effect appears to be independent of meat consumption, so enhancement of coronary artery disease risk by wheat consumption may be a possibility.

Because the unit of analysis in this study is the county, not the individual, it is impossible to know whether coronary artery disease and other chronic degenerative diseases are minimized because all members of the population eat a minimum of animal-based foods or because fewer individuals consume larger quantities of these foods. Either way, the findings indicate that coronary artery disease and similar chronic degenerative diseases become less common as the intake of animal-based foods and total dietary fat are minimized or eliminated. Assessment of disease risk for individuals will require a different type of study design.

## SUMMARY

In the China study, we used 2 general analytic strategies to examine the relations between diet and chronic degenerative disease. The first strategy sought disease aggregations, then identified the principal risk factors for these disease groups. The second strategy examined specific diet-disease associations, then evaluated their correlations with the average consumption of plant and animal-based foods. Both strategies resulted in the same conclusions. First, a diet comprising a variety of good-quality plant-based foods yields the lowest disease rates. Second, there is no evidence of a threshold beyond which further benefits do not accrue with increasing proportions of plant-based foods in the diet. Our study results have convinced us that consumption of a low-fat, plant-based diet can prevent and reverse a wide variety of chronic degenerative diseases.

Our major finding concerning coronary artery disease was that risk of this disease decreases with increased consumption of plant-based foods and decreased consumption of animal-based foods. This is true even in rural China, where coronary artery disease mortality rates are far below those in the United

States. Also, in this population, the correlations with plasma cholesterol, which is very low by Western standards, indicate that, to fully prevent coronary artery disease, plasma cholesterol must be maintained well under 150 mg/dL.

Nevertheless, we should try to understand the determinants of low coronary artery disease risk within the context of risks of other chronic degenerative diseases so that we do not trade one disease for others. Also, among the >8,000 statistically significant associations in this massive data set, some do not appear to agree with our hypothesis. These anomalies, however, are few, especially considering possible confounding. In short, it is important that investigations into the etiology of coronary artery disease examine all possible dietary and lifestyle associations.

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