The Garden of Eden

Plant-Based Diets, The Genetic Drive to Store Fat and Conserve Cholesterol, and Implications for Epidemiology in the 21st Century

David J. A. Jenkins,†‡ and Cyril W. C. Kendall*‡*

For most of the evolution of the hominoids (apes and humans), it seems likely that we depended on plant-based (vegetarian) diets[1–5]—very high in fiber, low in saturated fats, lacking in cholesterol, with carbohydrate in dilute form, rich in micronutrients and phytochemicals, and with very low energy density. The gibbon split from our clade over 20 million years ago. The orangutan departed 15 million years ago. The final break occurred 5 to 7 million years ago with the shift in tectonic plates that created the Rift Valley and sent gorilla, chimpanzee, and human to follow their separate paths of development. The gibbon, orangutan, and gorilla, and to a large extent the chimpanzee, continue with their plant-based diets.

Humans are the "odd men out." They left the jungle and colonized the savannah, they gathered plant materials for subsistence, and it has been suggested that they followed the big cats and other carnivores to compete with the jackal for the carrion.[6,7] Approximately 2.5 million years ago, *Homo habilis* ("handy man") developed stone tools from which the Acheulian hand ax developed (a flat pear-shaped cutting instrument). This all-purpose "Swiss army knife" allowed carrion skulls and long bones to be opened for brain and marrow—valuable sources of fat in a calorie-poor environment. With the further evolution of stone implements, most recently in the Paleolithic period, large-scale hunting became possible, and meat intake is hypothesized to have been high.[8] However, the species reductions and extinctions that followed successful hunting brought on the Neolithic agricultural revolution 10,000 years ago; for the first time, starch became a major dietary staple[9] and allowed our species numbers to multiply and enjoy a measure of security and affluence. With this advance came diabetes, described first by the ancient Egyptians. Since then, the industrial revolution and the industrialization of food production and distribution has fulfilled human needs for energy conservation (sloth) and abundance of food (gluttony). All these advances have taken place through increasingly rapid evolution of our tools, machines, and devices without corresponding evolution of the human genome.

We are therefore still programmed to store energy effectively. In an age of inactivity and abundance, we are increasingly obese. We are programmed to maintain our blood glucose levels even in starvation; thus, in affluence, we are increasingly diabetic. We are programmed to synthesize cholesterol for a low-calorie environment when there was an absence of saturated fat and dietary cholesterol. With our contemporary dietary pattern, half our middle-aged population have high blood cholesterol levels and could benefit from statins, currently the most efficacious class of drugs.

So overwhelming are these metabolic problems of 21st century civilization that we asked what effect a "primitive diet" might have on the biochemical indices of modern man.

From the *Clinical Nutrition & Risk Factor Modification Center; the †Department of Medicine, St. Michael's Hospital, Toronto, Ontario, Canada; and the ‡Department of Nutritional Sciences, Faculty of Medicine, University of Toronto, Ontario, Canada.
Correspondence: David J. A. Jenkins, Clinical Nutrition and Risk Factor Modification Center, St. Michael's Hospital, 61 Queen St. East, Toronto, Ontario, Canada, M5C 2T2. E-mail: cyril.kendall@utoronto.ca.

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RECONSTRUCTED SIMIAN AND NEOLITHIC DIETS

We therefore decided to reconstruct diets representing earlier phases in human evolution, feed them to contemporary humans for 2-week periods, and determine their physiological effects.[10] We selected to study 2 periods. One diet might have been eaten in the Miocene era, 4 to 7 million years ago. At that time, the range of foods eaten by our human ancestors was probably not very different from that of contemporary great apes, whose genetic makeup is possibly no more than 2% to 3% different from modern humans.[11] This first diet consisted of large amounts of leafy vegetables, nuts (almonds and hazelnuts), and fruit, some tropical, but all purchased in local grocery stores. Theoretically, all these foods could be eaten raw but the majority of vegetables were eaten cooked. The diet was effectively devoid of any significant amount of starch. This diet was compared for effect on serum cholesterol with 2 current diets. First was a high-starch Neolithic-like diet, low in saturated fat and high in oats, barley, whole grain cereals, and dried legumes, with low-fat dairy as the source of animal protein. The second diet was a modern therapeutic diet (NCEP step 2 diet)—very low in saturated fat and dietary cholesterol and with a similar macronutrient profile to the "Simian" Miocene diet.

The major feature of the Simian diet was the large volume and the length of time spent eating. Considerable pressure had to be brought to bear on the subjects to ensure they ate all their food and did not lose weight. The foods were palatable, but the volume of 5.5 kg/d for a 70-kg man was excessive and the time taken to eat this volume (8 or more hours per day) was a further limitation. At the end of the 2-week diet periods of weight maintenance, low-density lipoprotein (LDL) cholesterol was reduced on the Simian diet by 33%, on the Neolithic diet by 23%, and on the therapeutic diet by 7% (Fig. 1). Perhaps more importantly, the respective LDL:high-density lipoprotein cholesterol ratios were reduced by 24%, 12%, and 5%.

The cholesterol reductions on the Simian diet were similar to the reductions achieved with the first-generation statins. Bile acid losses reached 1 g/d in the men, a 4-fold increase over the therapeutic diet. Analysis of the diet for components that might alter cholesterol metabolism showed that the Simian diet provided approximately 1 g of plant sterols daily, 145 g of fiber, and 92 g of vegetable protein and on average over 70 g almonds or hazelnuts per day. The first 2 components would have reduced cholesterol and bile acid absorption and thus increased fecal steroid loss[12–14]; the vegetable proteins would have reduced hepatic cholesterol synthesis[15] as evidenced by reduced urinary mevalonic acid output. The nuts would have provided monounsaturated fats, vegetable protein, and plant sterols, all of which would tend to lower serum cholesterol. These diets would be predicted to upregulate LDL receptors.[16,17]

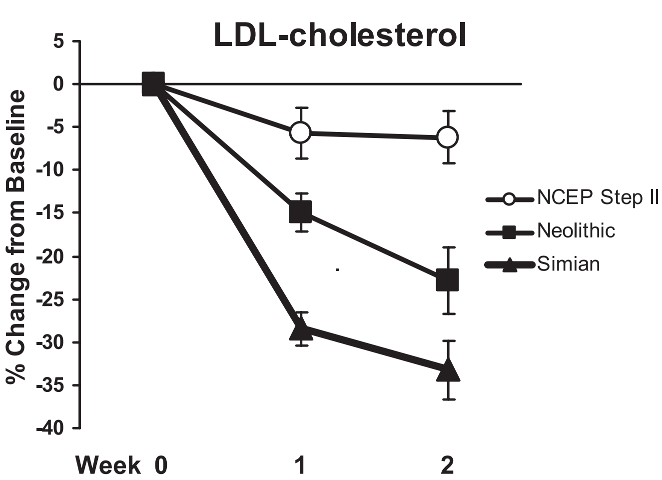

FIGURE 1. Percent reductions from baseline in low-density lipoprotein cholesterol on the NCEP step II, "Neolithic," and "simian" diets.[10]

This study suggested that serum cholesterol levels were likely to have been low throughout the course of human evolution and that reintroduction of foods containing cholesterol-lowering components might reduce the current apparent dependency on drugs for cholesterol control in the 21st century and beyond.

In relation to obesity, the volume of the food that had to be eaten on the Miocene/simian diet, was a clear indication that "overconsumption" would not be a problem and indicated the importance of food volume in appetite control. Furthermore, the time spent eating would pose a further major barrier to overconsumption.

The implications of these findings for current epidemiologic research are many. Food volume, eating time, and the percentage of calories derived from plant foods deserve to be documented carefully. Physical activity remains a key variable. In the long run, perhaps the most important issue in the epidemiologic debate will be how to both preserve human health and promote a healthy environment in which the fast-dwindling numbers of our great ape cousins can also share.

ABOUT THE AUTHORS

DAVID JENKINS is a professor in the Departments of Medicine and Nutritional Sciences, Faculty of Medicine, University of Toronto, a staff physician in the Division of Endocrinology and Metabolism, and the Director of the Clinical Nutrition and Risk Factor Modification Center, St. Michael's Hospital. CYRIL KENDALL is a Research Associate in the Department of Nutritional Sciences, University of Toronto, and the Clinical Nutrition and Risk Factor Modification Center, St. Michael's Hospital, and also an Adjunct Professor in the Department of Pharmacy at the University of Saskatchewan. They are currently running clinical studies on the effect of diet in the prevention and treatment of cardiovascular disease, diabetes, and obesity.

REFERENCES

1. Milton K. Nutritional characteristics of wild primate foods: do the diets of our closest living relatives have lessons for us? *Nutrition*. 1999;15:488–498.
2. Popovich DG, Jenkins DJ, Kendall CW, et al. The western lowland gorilla diet has implications for the health of humans and other hominoids. *J Nutr*. 1997;127:2000–2005.
3. Cousins D. A review of the diets of captive gorillas (Gorilla gorilla). *Acta Zool Pathol Antverp*. 1976;66:91–100.
4. Kay R. Diets of early Miocene African hominoids. *Nature*. 1977;44: 628–630.

5. Milton K. Primate diets and gut morphology. Implications for hominid evolution. In: Harris M, Boss EB, eds. *Food and Nutrition: Toward a Theory of Human and Food Habits.* Philadelphia: Temple University Press; 96–116.
6. Cordain L, Watkins BA, Florant GL, et al. Fatty acid analysis of wild ruminant tissues: evolutionary implications for reducing diet-related chronic disease. *Eur J Clin Nutr*. 2002;56:181–191.
7. Cordain L, Miller JB, Eaton SB, et al. Plant-animal subsistence ratios and macronutrient energy estimations in worldwide hunter–gatherer diets. *Am J Clin Nutr*. 2000;71:682–692.
8. Eaton SB, Konner M. Paleolithic nutrition. A consideration of its nature and current implications. *N Engl J Med*. 1985;312:283–289.
9. Cordain L. Cereal grains: humanity's double-edged sword. *World Rev Nutr Diet*. 1999;84:19–73.
10. Jenkins DJ, Kendall CW, Popovich DG, et al. Effect of a very-high-fiber vegetable, fruit, and nut diet on serum lipids and colonic function. *Metabolism*. 2001;50:494–503.
11. Kaessmann H, Paabo S. The genetical history of humans and the great apes. *J Intern Med*. 2002;251:1–18.
12. Kay RM, Truswell AS. Effect of citrus pectin on blood lipids and fecal steroid excretion in man. *Am J Clin Nutr*. 1977;30:171–175.
13. Jenkins DJ, Wolever TM, Rao AV, et al. Effect on blood lipids of very high intakes of fiber in diets low in saturated fat and cholesterol. *N Engl J Med*. 1993;329:21–26.
14. Lees AM, Mok HY, Lees RS, et al. Plant sterols as cholesterol-lowering agents: clinical trials in patients with hypercholesterolemia and studies of sterol balance. *Atherosclerosis*. 1977;28:325–338.
15. Kurowska EM, Carroll KK. Effect of high levels of selected dietary essential amino acids on hypercholesterolemia and down-regulation of hepatic LDL receptors in rabbits. *Biochim Biophys Acta*. 1992;1126: 185–191.
16. Lovati MR, Manzoni C, Canavesi A, et al. Soybean protein diet increases low density lipoprotein receptor activity in mononuclear cells from hypercholesterolemic patients. *J Clin Invest*. 1987;80:1498–1502.
17. Baum JA, Teng H, Erdman JW Jr, et al. Long-term intake of soy protein improves blood lipid profiles and increases mononuclear cell low-density-lipoprotein receptor messenger RNA in hypercholesterolemic, postmenopausal women. *Am J Clin Nutr*. 1998;68:545–551.