



It's more than an apple a day: an appropriately processed, plant-centered dietary pattern may be good for your health^{1,2}

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Despite widespread acceptance that the consumption of fruit and vegetables is good for health (1), formal research on the intake of these foods in relation to cardiovascular disease is surprisingly sparse (2). In this issue of the Journal, Liu et al (3) present evidence concerning risk of incident atherosclerotic cardiovascular disease among older women according to fruit and vegetable intake. Observed risk was $\approx 30\%$ lower in the women who ate 5–10 servings of fruit and vegetables per day than in those who ate 2.5 servings/d. Higher fruit and vegetable intake went hand in hand with other presumably healthful lifestyle habits. After adjustment for these and other cardiovascular disease risk factors, the risk reduction was attenuated to $\approx 15\%$, still inverse but no longer statistically significant. The risk reduction was stronger and statistically significant in women without diabetes, hypertension, hypercholesterolemia, and other high-risk conditions.

For many years, interest has centered on the lipid dimension of dietary intake, ie, saturated fat, *trans* fat, and cholesterol because of their relation to serum cholesterol and the atherosclerotic process (4–6). However, dietary fat does not seem to be the only influential dietary dimension, others being appropriately processed plant foods, fish, and low-fat dairy products. As pointed out by Liu et al (3), fruit and vegetables are an obvious target of research. There is increasing evidence that plant foods may help prevent atherosclerosis, not just by substituting for undesirable fat, but in their own right (1, 7–10).

Our conception is that a broad array of plant constituents may be healthful for humans. Such constituents may go beyond macronutrients and well-accepted micronutrients such as antioxidant vitamins, minerals, and phytoestrogens. These include plant enzymes, hormones, and other substances that help to regulate plant metabolism as well as natural phytochemicals that protect the plant against predators such as insects or fungus or attract insects or birds for pollination. Analogous biochemical function is probably less developed in animals. It is an attractive hypothesis that this plant biological activity confers benefit when consumed by humans, notwithstanding the possibility of harm when single plant foods or phytochemicals are consumed in great excess (11). Indeed, cardiovascular disease risk appears to be reduced in those who eat plant products other than fruit and vegetables, including whole grains (8–10, 12, 13) and nuts (13, 14). These foods probably act on human chronic disease processes in a highly complex fashion.

Clinical trials provide further support for the efficacy of complex, plant-centered food patterns. In one trial, consumption of a

Mediterranean diet reduced coronary events by 75% and total death by 56% (15); in another trial, a diet high in fruit and vegetables, in which some whole-grain foods replaced refined-grain foods, reduced blood pressure (16). The Diet and Reinfarction Trial (17) is controversial because reduced dietary total and saturated fat had no significant effect on the 2-y mortality rate, whereas increased dietary cereal fiber seemed to increase mortality, although not significantly. Seen more closely, however, the 250 men who received advice that addressed 3 dietary dimensions—increase cereal fiber intake, decrease dietary fat, and increase fish intake—had a lower death rate during 2 y of follow-up than did parallel treatment groups who received less comprehensive dietary advice. The dietary pattern that resulted from the 3-pronged advice included more plant products, including whole grains, and the substitution of fish for red meat. Several parallel treatment groups who received less comprehensive advice had a higher-than-average mortality rate. Thus, despite the questionable statistical significance of the findings of Liu et al, we believe that fruit and vegetable consumption is one component in a causal pathway linking plant food in the diet to reduced risk of atherosclerotic and probably other chronic diseases.

Although the idea that plant foods are healthful is not new, the findings of Liu et al point in a new direction. First, although we do not think that red meat must be eliminated, a plant-centered diet should be even more strongly encouraged than it is now. Simple visual methods should be used to communicate the plant-centered plate to the public (18). Second, the nutrients available to the public in foods are not being fully realized. It is common in the United States to eat plant foods adulterated by processing or cooking, eg, French fries and other deep-fried products in which the nutrient-rich potato peel is generally removed and the fat is usually oxidized; refined grain, in which the nutrient-rich bran and germ are removed; and ketchup, which consists of tiny amounts of tomato eaten with large amounts of sodium. A change in these practices could bring a

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much richer mix of nutrients to Americans. For example, total grain consumption in the United States makes up $\approx 23\%$ of energy intake, but whole grain makes up only $\approx 1\%$ (8).

We are concerned about the tendency to focus on dietary supplements or formulated functional foods, which, in our opinion, overemphasize single nutrients. Use of functional foods for general public consumption is different from their use for a specific intervention, such as β -sitosterol incorporated in margarine for those who have high blood lipid concentrations. Advertising with a focus on function of a single nutrient distracts from public attention to the task of maximizing intake of otherwise available nutrients. It is also potentially worrisome whether there would be long-term effects of changing the balance of the components of the food. We challenge the food industry to sort out the most appropriate methods to preserve, store, and prepare food products to maximize delivery of a broad range of food components rather than focus on functional foods that are perceived as a quick fix by the public. Food itself is important: it is not an empty vessel carrying single nutrients such as calcium, it is the ultimate source of all nutrients.

It is not only industry that takes a single-nutrient approach. Much of nutritional science, in a legitimate effort to understand basic pathologic mechanisms, has followed a reductionist approach, examining effects of single nutrients and supplements thereof. A lesson was learned from prospective studies of β -carotene and reduced risk of cancer (19). Subsequent clinical trials found no effect of relatively high doses of isolated β -carotene. It is probable that β -carotene as represented in the prospective studies was actually a biomarker for a dietary pattern rich in a variety of minimally processed plant foods. We think it will be a long time before science unravels the complexity of nutrient interactions in the relation of foods to health.

Although studies of single or pairs of nutrients should obviously continue, much attention should also be paid to foods themselves, as packages of nutrients, and to food patterns. An appropriate study design would be to feed a diet based on a food pattern and then observe the effects (15–17). Such a design automatically incorporates all nutrient interactions in the food pattern. Ultimately, studies using a “top-down logic,” in which certain foods are deleted from the complex pattern, will suggest which combinations of foods or nutrients are most influential. 

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