Food Variety Is Associated with Less Macrovascular Disease in Those with Type II Diabetes and Their Healthy Controls

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In developed countries, the health outcome most under scrutiny with respect to food intake is macrovascular disease. Since food is so complex, global indices of food intake are required to assess the relation. In the present study, an index of food variety was examined for its ability to predict changes in the arterial wall. Arterial wall indices were measured noninvasively by Doppler ultrasound in patient with Type II diabetes and in matched apparently healthy subjects. Each subject kept a 7-day food record, which was cross-checked by a nutritionist so as to calculate an index of food variety. The arterial wall indices measured were compliance over the aorto-iliac segment and pulse wave damping at the common femoral and posterior tibial arteries. Significant correlations, both parametric and nonparametric, were found between total food variety, and plant food variety, and each arterial wall index when the diabetics and apparently healthy subjects were grouped together ($p < 0.01$ in all cases for total variety and at least < 0.05 for plant food variety). Between 13 and 19% of the variance in arterial wall indices was explained by food variety.

INTRODUCTION

Encouragement to consume a wide variety of foods is now a dietary guideline in most developed countries [1–3]. It is agreed that most of homo sapiens' food experience has been as a hunter-gatherer, so that many different kinds of foods have provided a wide range of essential nutrients and have diluted out potentially toxic components. However, formal study of the predictive power of food variety for health outcomes is in its infancy.

It has been considered appropriate that dietary guidelines for the nutritional management of diabetes should be the same as for the population at large, with additional emphasis on regularity and distribution of food intake [1]. Again, the specific role of food variety has not been examined, but there is a growing recognition that several food components can influence blood glucose control in diabetes. More integrative indices of food, such as the glycemic index, should be sought to achieve better control [4].

Emphasis on food factors which affect blood glucose control in diabetes is not enough. The sequelae of macrovascular disease are the major causes of premature death in patients with diabetes [5], so that an effort is required to understand better the links between food intake and macrovascular disease. Macrovascular disease in diabetes may well be more than atherosclerotic vascular disease (AVD).

In previous studies, we used arterial compliance and pulse-wave damping, two quite independent techniques, measured noninvasively by Doppler ultrasound, to assess macrovascular disease in apparently healthy subjects and in diabetics, at a stage where there was no clinical evidence of occlusive arterial disease. Classical risk factors for AVD — such as age, serum total cholesterol, serum HDL cholesterol, and blood pressure — were shown to be

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Table 1. Subject Characteristics[a]

	Age (year)	BMI[b] (kg m^{-2})	$\overline{BP}$[c] (mm Hg)	Glycated hemoglobin (g 100 g^{-1})
Healthy				
Men (7)	67 ± 3	28 ± 2	99 ± 3	5.9 ± 0.5
Women (24)	69 ± 2	27 ± 1	94 ± 2	6.1 ± 0.2
Type II diabetes				
Men (10)	63 ± 3	26 ± 1	98 ± 3	6.9 ± 0.5
Women (12)	69 ± 3	30 ± 1	100 ± 2	7.8 ± 0.4

[a] The number of subjects is shown in parentheses. The mean ± SD are shown.
[b] BMI is body mass index.
[c] $\overline{BP}$ is the geometric mean blood pressure = [systolic + 2(diastolic)]/3.

predictive of arterial compliance in both groups [6,7].

In the present study, apparently healthy subjects and patients with Type II diabetes on dietary management alone have been studied for arterial wall characteristics in relation to the variety of food intake. None of the subjects had clinical evidence of occlusive peripheral arterial disease.

METHODS

Subjects

The study was approved by the Ethics Committee at Prince Henry's Hospital in accordance with the statement on human experimentation by the National Health and Medical Research Council of Australia. Informed consent was obtained.

The study involved 31 apparently healthy subjects (seven men and 24 women) and 22 patients with non-insulin-dependent diabetes (NIDD) managed by diet alone (10 men and 12 women) [8]. The two groups were matched for age, height, weight, and blood pressure (Table 1). Ahead of the study, all of those with diabetes were counseled to adhere to a food intake pattern low in saturated fat and high in unrefined carbohydrates.

None of the subjects were smokers, and all were normotensive (diastolic pressure < 95 mm Hg). No subject had any symptoms or past history of arterial disease. None of the diabetics had evidence of retinopathy, nephropathy, or neuropathy. All had normal ankle pressure indices at rest and following exercise (measured using Doppler ultrasound).

Analytical Method

Glycated hemoglobin was measured using the Helena glycated (fast fraction) hemoglobin Quik column kit [9,10].

Food Intake

All subjects (apparently healthy and NIDD) completed a 7-day dietary record during the week after the Doppler studies. A clinical nutritionist then met with each subject to review the diet record and clarify information necessary for data coding. Neither the subjects nor the nutritionist knew the results of the arterial wall studies. Food models were used to estimate quantities and types of food consumed. An index of food variety was developed from a biological classification of food for human nutrition [11]. Food was broadly categorized into animal and plant-derived and then subcategorized (Table 2). On this basis, the maximum variety was 53. The variety achieved in a week was scored out of this maximum. Although the data are available, the index makes no

Table 2. Foods Grouped According to Biological Source

Group	Group
Animal	Pastry
Eggs	Biscuits
Milk	Cake
Dairy (e.g., cheese, yogurt)	Pasta
Fish	Bread — white wheat flour
Shellfish (e.g., mussels, oysters)	Bread — wholemeal wheat flour
Crustaceans (e.g., prawns, lobster)	**Fruits**
Ruminants (e.g., sheep, cattle)	Citrus (e.g., oranges, lemons)
Monogastric (e.g., pig)	Tropical fruit (e.g., mango, papaya banana)
Poultry (e.g., chicken, duck, turkey)	Stone fruit (e.g., plums, apricots, cherries, peaches)
Game (e.g., rabbit, bird, kangaroo)	Apples
Liver	Pears
Brain	Berries (e.g., strawberries, raspberries)
Giblets (e.g., kidneys, heart, intestines)	**Nuts**
Plant	**Confectionery**
Vegetables	Lollies
Root, white (potatoes)	Chocolate
Root, yellow (carrots)	**Yeast**
Leafy (e.g., spinach, cabbage)	**Jam**
Marrow	**Added fat**
Flowers (e.g., broccoli, cauliflower)	**Added sugar**
Stalks (celery)	**Beverages**
Onion-like (e.g., spring onions)	Tea
Tomato	Coffee
Peppers (capsicum)	Alcohol
Legumes (e.g., beans, peas, lentils)	Soft drink
Mushroom and other fungi	Water
Cereals and Grains	
Morning cereal	
Corn	
Oats/porridge	
Rye (bread)	
Rice	

assumption about quantity, other than that at least an average serving size was required for the food to score [11].

Doppler Ultrasound Studies

Each subject was rested supine for at least 10 minutes and the examination began when the blood pressure was stable. Mean compliance between the left subclavian artery and each femoral artery at the inguinal ligament was calculated from pulse wave velocity (PWV) recorded by two 4-MHz Sonicaid Doppler ultrasound probes (Sonicaid Medical Inc., Virginia) through a Medishield spectrum analyzer (Medishield Corp. Ltd., London), as described previously [7,12]. The PWV down the aorto-iliac seg-

Table 3. Indices of Food Variety in Type II Diabetes and Their Healthy Controls[a]

	Male		Female		Combined	
	Diabetes (n = 10)	Healthy (n = 7)	Diabetes (n = 12)	Healthy (n = 24)	Diabetes (n = 53)	Healthy (n = 53)
Food variety	19.9 ± 1.3	25.7 ± 2.2*	21.8 ± 1.1	24.6 ± 0.9[ns]	21.0 ± 0.8	24.9 ± 0.8**

[a]Mean ± SE are shown. n is the number of subjects and is shown in parentheses. The significance of the difference between those with diabetes and healthy subjects is indicated by ns ($p > 0.05$, actually < 0.06 in this case), *($p < 0.05$) and **($p < 0.01$, actually < 0.005 in this case).

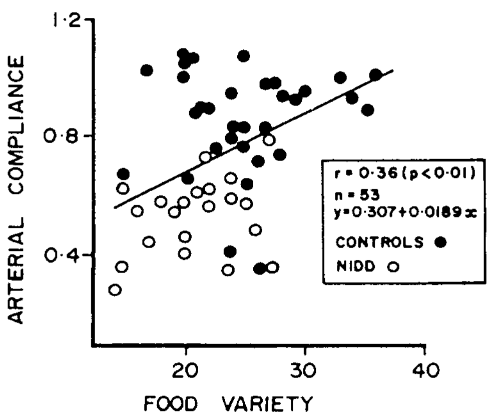

Fig. 1. Relationship between aorto-iliac arterial compliance and food variety.

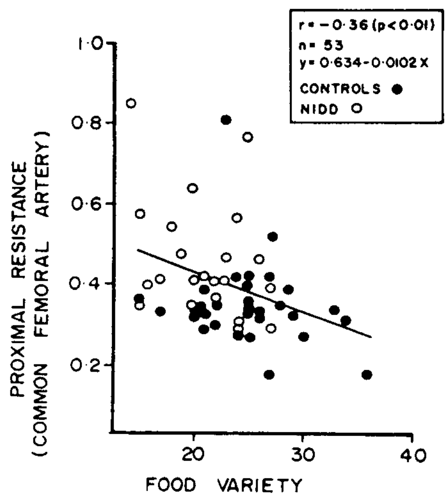

Fig. 2. Correlation between proximal resistance (pulse-wave damping) at the common femoral artery and food variety.

ments was calculated from the ratio of time delay [T (in seconds)] and the measured distance between the probes [L (m)] as $PWV = L/T$ ms^{-1}, and the compliance (C) is calculated as $C = 66.7/(PWV)^2$. Each measurement consisted of the mean of 10 pulse wave calculations on each side. Pulse-wave damping (PWD) at the common femoral arteries and at the posterior tibial arteries were determined with an 8-MHz vascular Sonicaid Doppler ultrasound probe through the Medishield spectrum analyzer. A Fourier analysis of the pulse wave at each site was performed by a Data General Nova II computer, and this allowed calculation of the Laplace damping factor or pulse-wave damping, which is considered to be related to proximal resistance, as described previously [7,13].

Statistical Analysis

Differences between groups have been assisted by Student's t-test. Relationships between arterial wall indices and the indices of food variety were examined by parametric and nonparametric (Spearman rank) correlation analyses [14].

RESULTS

Indices of food variety were lower in those with diabetes than in healthy subjects (Table 3).

The relationships between the results for the arterial indices and the index of food variety are

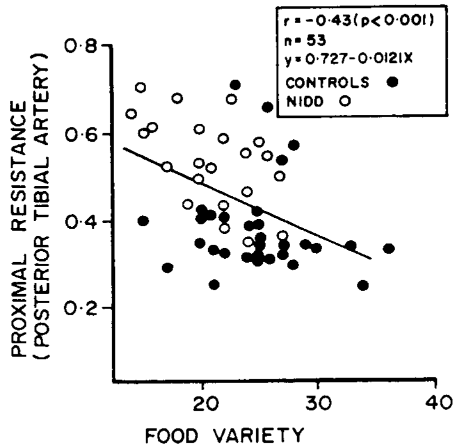

Fig. 3. Correlation between proximal resistance (pulse-wave damping) at the posterior tibial artery and food variety.

shown in Table 4. The spectrum of glucose tolerance was expanded by grouping the apparently healthy subjects and those with Type II diabetes together. Significant relationships were seen in all cases and for all subjects combined, and the arterial variance explained was 13–19%. Otherwise, the best relationships were seen with men, in Type II diabetes, and for posterior tibial PWD. The relationships are such that as food variety increases so also does arterial compliance, while PWD decreases (Figs. 1–3). It is also of interest that increased variety amongst plant foods eaten was predictive of better arterial compliance in the study population as a whole and of decreased PWD in Type II diabetes (Table 5).

DISCUSSION

Population Studied

We see relevance for considering subjects with a range of glucose tolerance or blood glycated hemoglobin measurements. The rationale for combining NIDD with apparently healthy subjects for correlation analysis was to provide a sufficiently wide range of arterial wall indices to recognize determinants. Impaired glucose tolerance (IGT), intermediate between what is regarded as normal and diabetes defined by WHO criteria [8,15], carries an increased risk for macrovascular disease and its sequelae [5–7]. What does distinguish diabetes from IGT is the propensity to microvascular disease such as background retinopathy. Thus, it seems both reasonable and desirable to consider a continuum from normality through IGT to clinical diabetes. In this study, we did not consider Type II diabetes managed by oral agents or Type I (insulin-dependent) diabetes.

Food Factors

It must be stressed that the analysis of food intake here is with respect of current and not past diet, both for diabetic and healthy subjects. Furthermore, there is no matching of subjects in either group as far as food habits are concerned, so that the usual range of food habits in each group has been maintained. What is important, then, is that, across a range of diets and degrees of glucose tolerance, food variety in the current diet has been shown to act as a determinant of arterial wall indices. This has implications for guidelines for prevention of macrovascular disease. Adherence to dietary recommendations in patients

Table 4. Relationships between Arterial Indices and Food Variety in Males and Females, Type II Diabetics, and Apparently Healthy Subjects, and the Combination of the Two Groups[a]

	Male (n = 17)		Female (n = 36)		Healthy (n = 31)		Type II diabetics (n = 22)		Combined (n = 53)	
	r	r_s	r	r_s	r	r_s	r	r_s	r	r_s
Aorto-iliac compliance	0.56*	0.59*	0.19	0.18	0.01	0.00	0.31	0.34	0.36**	0.38**
Pulse-wave damping										
Common femoral	−0.60*	−0.52*	−0.24	−0.32*	−0.19	−0.17	−0.30	−0.32	−0.36**	−0.38**
Posterior tibial	−0.55*	−0.64*	−0.32*	−0.35*	−0.10	−0.20	−0.54**	−0.52**	−0.43**	−0.44**

[a] n is the number of subjects and is shown in parentheses; r is the correlation coefficient; r_s is Spearman's rank (nonparametric) correlation. The significance of a correlation coefficient is indicated by ns ($p > 0.05$), *($p < 0.05$), and **($p < 0.01$).

Table 5. Relationships between Arterial Indices and Plant Food Variety in Males and Females, Type II Diabetics, and Apparently Healthy Subjects, and the Combination of the Two Groups[a]

	Male (n = 17)		Female (n = 36)		Healthy (n = 31)		Type II diabetics (n = 22)		Combined (n = 53)	
	r	r_s	r	r_s	r	r_s	r	r_s	r	r_s
Aorto-iliac compliance	0.46	0.32	0.19	0.09	0.01	0.02	0.22	0.16	0.32*	0.31*
Pulse-wave damping										
Common femoral	−0.58*	−0.46	−0.16	−0.14	−0.14	−0.09	−0.20	−0.20	−0.30*	−0.31*
Posterior tibial	−0.50*	−0.53*	−0.32*	−0.24	−0.06	−0.28	−0.55**	−0.47*	−0.39**	−0.41**

[a] n is the number of subjects and is shown in parentheses; r is the correlation coefficient; r_s is Spearman's rank (nonparametric) correlation. The significance of a correlation coefficient is indicated by ns ($p > 0.05$), *($p < 0.05$), and **($p < 0.01$).

with Type II diabetes is low [16,17] and achieved by about 50% of the diabetic population at Prince Henry's Hospital in Melbourne, the hospital where the present study has been conducted. Thus, to a large extent, the diets of diabetics studied were their usual prediabetic diets. Some will have made changes to their diet, but such changes have not been taken into account in this study. What is all the more interesting, then, is that the food variety index in those with diabetes was less than in healthy controls. There may well be a spectrum of food variety score from health to diabetes and the distribution of our scores suggests a continuum (Figs. 1–3). It is an intriguing possibility raised by this study that a narrow range of foods may antedate diabetes or even predispose to its expression.

Macrovascular Disease

We have previously argued that, where the interest is in macrovascular disease, a study design which allows the range of glucose tolerance from normality, through impairment, to Type II diabetes with no pharmacological management, is appropriate for examining the determinants of macrovascular disease [18]. It also has the potential for providing a wider range of such determinants. There is no reason to expect a bimodal distribution of arterial wall characteristics in our study population, and, indeed, we did not find it. The highly significant relationship of PWD in the posterior tibial artery to food variety, however, argues that food variety is of special relevance to an artery known to be particularly disposed to macrovascular disease in diabetes.

It cannot be said that arterial wall changes recognized in the study reflect AVD. Presumably some is AVD, as we have shown that arterial compliance is dependent on classical risk factors for AVD in healthy subjects and diabetics without clinical evidence of occlusive arterial disease [6,18]. However, another possible contributor to reduce arterial compliance in diabetics is glycation of arterial wall proteins [15], and, for this reason, we prefer to discuss our findings in terms of macrovascular disease rather than AVD.

The present study has shown that it is possible to examine arterial wall characteristics noninvasively in relation to a global index of food intake, namely food variety. The approach undertaken here opens up new opportunities for exploring food intake patterns in relation to arterial disease.

REFERENCES

1. Wahlqvist ML: Diet in the treatment of diabetes. Med J Aust 2:64–68, 1980.
2. Wahlqvist ML: Dietary guidelines in Australia. In Wahlqvist ML, King R, McNeill J, Sewell R (eds): "Food and Health: Issues and Directions." London: J Libbey and Co, pp 112–115, 1987.
3. English R: "Towards Better Nutrition for Australians." Canberra: Australian Government Publishing Services, pp 63–64, 1987.
4. Jenkins DJA, Wolever TMS, Jenkins AL, Thome MJ, Lee R, Kalmusky J, Reichert R, Wong GS: The glycemic index of foods tested in diabetic patients: a new basis for carbohydrate exchange favouring the use of legumes. Diabetologia 24:257–264, 1983.
5. Wahlqvist ML, Relf IRN, Myers KA, Lo CS: Diabetes and macrovascular disease: risk factors for atherogenesis and non-invasive investigation of arterial disease. Hum Nutr Clin Nutr 38C:175–184, 1984.
6. Relf IRN, Lo CS, Myers KA, Wahlqvist ML: Risk factors for changes in aorto-iliac arterial compliance in healthy men. Arteriosclerosis 6:105–108, 1986.
7. Lo CS, Relf IRN, Myers KA, Wahlqvist ML: Doppler ultrasound recognition of preclinical arterial disease in diabetes: compliance and pulse-wave damping. Diabetes Care 1:27–31, 1986.
8. WHO Study Group: "Diabetes Mellitus," Technical Report Series 727. Geneva: WHO, 1985.
9. Hammons GT, Jurger K, McDonald JM, Ladension JH: Evaluation of three minicolumn procedures for measuring hemoglobin AIc. Clin Chem 25:1775–1778, 1982.
10. Lee LPK, Arnott B, Feng M: Comparison of four commercial methods for determination of fast haemoglobins. Clin Biochem 15:230–233, 1982.
11. Briggs DR, Wahlqvist ML: "Food Facts." Melbourne: Penguin Books, 1985.
12. Gosling RG: "Extraction of Physiological Information from Spectrum-Analysed. Doppler-Shifted Continuous-Wave Ultrasound Signals Obtained Non-Invasively from the Arterial System." Herts: IEE Medical Electronics, Perigrinus, pp 73–125, 1976.
13. Skidmore R, Woodcock JP: Physiological interpretation of Doppler-shift wave forms, 1: theoretical con-

sideration. Ultrasound Med Biol 6:7–10, 1980.

14. Siegel S: The Spearman rank correlation coefficient: r_s. In "Non-Parametric Statistics for the Behavioral Sciences." New York: McGraw-Hill International Student Editions, pp 202–239, 1974.
15. Cerami A, Vlassara H, Brownless M: Protein glycosylation and the pathogenesis of atherosclerosis. Metabolism 12:37–44, 1985.
16. Truswell AS, Thomas BJ, Brown AM: Survey of dietary policy and management in British diabetic clinics. Br Med J 4:7–11, 1975.
17. Kouris AA, Wahlqvist ML, Worsley A, Bruere T, Cameron C, Morrison B, Brazier J: Population characteristics of people with diabetes for whom adherence to a high carbohydrate fibre diet is required. Proc Nutr Soc Aust 10:127, 1985.
18. Wahlqvist ML, Lo CS, Myers KA, Simpson RW, Simpson JM: Putative determination of arterial wall compliance in NIDDM. Diabetes Care 11:787–790, 1988.

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