CLINICAL RESEARCH

Plasma lipids and lipoprotein cholesterol concentrations in people with different diets in Britain

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Abstract

Concentrations of total cholesterol and cholesterol in the various lipoprotein fractions were measured in vegans, vegetarians, fish eaters (who did not eat meat), and meat eaters. Total and low density lipoprotein cholesterol concentrations were higher in meat eaters than vegans, with vegetarians and fish eaters having intermediate and similar values. High density lipoprotein cholesterol concentration was highest in the fish eaters but did not differ among the other groups. There were striking trends with age in total and low density lipoprotein cholesterol concentrations, which differed between men and women: women showed a steady increase in concentration with age, whereas concentrations in men did not increase appreciably after the age of 40, which may partly explain sex differences in the prevalence of coronary heart disease.

The differences in total cholesterol concentration suggest that the incidence of coronary heart disease may be 24% lower in lifelong British vegetarians and 57% lower in lifelong vegans than in meat eaters.

Introduction

Differences in blood cholesterol concentrations explain much of the cross cultural variation in the prevalence of coronary heart disease.[1] In high risk populations there is a linear association between cholesterol concentrations and the incidence of coronary heart disease.[2] The proportion of energy intake derived from saturated fat is an important determinant of differences in blood cholesterol concentration among populations.[1] In epidemiological studies of people in populations with high prevalences of coronary heart disease, however, the effect of dietary factors on lipid concentrations is less striking.[3] Several studies have shown lower cholesterol concentrations in vegetarians than in those who eat meat,[4-6] but few data are available for vegans and fish eaters. Vegetarian diets and high intakes of fish are associated with reduced risk of coronary heart disease.[7-10] We collected blood samples from vegans, vegetarians, fish eaters, and meat eaters to study in more detail the effect of diet on lipoprotein cholesterol concentrations in the British population, in whom cholesterol concentrations and the prevalence of coronary heart disease are among the highest in the world.

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Subjects and methods

Six thousand subjects who do not eat meat and 5000 meat eating controls are participating in a nationwide long term prospective study. Initially, members of the Vegetarian Society of the United Kingdom were invited to participate. Later a further request for volunteers was made by advertisements in various publications and on national and local radio. The control group consists of meat eating friends and relatives of those who do not eat meat. Recruitment took place from September 1980 to January 1984. From April 1984 to January 1986 all participants under the age of 70 were sent a kit consisting of a 10 ml heparinised tube, a syringe, and explanatory letters to them and their general practitioners. Doctors and their staff were requested to obtain a blood sample, which was sent by post to our laboratory in the special package provided. At the time of writing blood samples had been received from 114 vegans, 1550 lacto-ovovegetarians, 415 fish eaters (who did not eat meat), and 1198 meat eaters. Participants were allocated to these dietary groups on the basis of data obtained from a simple questionnaire completed on entry to the study.

On arrival in the laboratory blood samples were spun down and total cholesterol concentrations and concentrations of cholesterol in the various lipoprotein subfractions measured with a Technicon autoanalyser (second generation). Plasma was diluted and total cholesterol concentration measured directly by the cholesterol oxidase peroxidase antiperoxidase enzymatic method. Two further aliquots of plasma were taken; in one aliquot very low density lipoprotein and low density lipoprotein were precipitated by the heparin-manganese method, so that high density lipoprotein cholesterol could be measured in the supernatant. In the other aliquot very low density lipoprotein was precipitated with sodium dodecyl-sulphate, leaving high and low density lipoproteins in solution. Quantities of cholesterol in the various subfractions were calculated by subtraction.

Triglyceride concentrations were not measured because blood samples were not collected under standard (fasting) conditions. We have shown previously that lipid analyses may be made successfully on blood samples sent by first class post.[11]

TABLE I—*Numbers in each age group by diet and sex*

Age group (years)	Men				Women			
	Vegan	Vegetarian	Fish eater	Meat eater	Vegan	Vegetarian	Fish eater	Meat eater
≤29	14	147	33	99	28	383	78	175
30-39	19	152	54	171	15	280	103	233
40-49	3	74	18	89	10	142	58	120
50-59	7	69	7	66	11	148	36	101
≥60	2	59	10	61	5	96	18	83
Total	45	501	122	486	69	1049	293	712

TABLE II—*Mean age (years) by sex and diet*

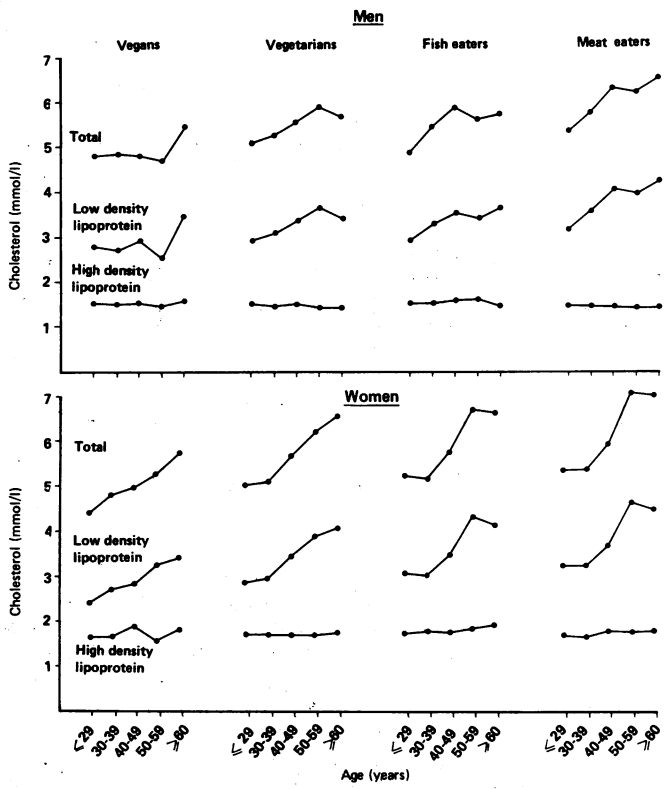
Diet	Men	Women
Vegan	36·2	37·1
Vegetarian	39·1	37·3
Fish eater	36·8	37·8
Meat eater	40·6	40·0

TABLE III—*Mean (SE) concentrations (mmol/l) of total cholesterol, low density lipoprotein cholesterol, and high density lipoprotein cholesterol adjusted for age and sex and ratio of low density lipoprotein cholesterol concentration to high density lipoprotein cholesterol concentration by diet*

Diet	Total cholesterol	Low density lipoprotein cholesterol	High density lipoprotein cholesterol	Low density lipoprotein cholesterol:high density lipoprotein cholesterol
Vegan	4·29 (0·140)	2·28 (0·126)	1·49 (0·048)	1·63 (0·120)
Vegetarian	4·88 (0·100)	2·74 (0·090)	1·50 (0·035)	1·95 (0·086)
Fish eater	5·01 (0·109)	2·88 (0·098)	1·56 (0·038)	1·97 (0·093)
Meat eater	5·31 (0·101)	3·17 (0·091)	1·49 (0·035)	2·27 (0·087)

Results

Table I shows the numbers of men and women in the different dietary groups and table II their mean ages. Table III shows the concentrations of total, low density lipoprotein, and high density lipoprotein cholesterol adjusted for age and sex and the ratio of low density lipoprotein to high density lipoprotein cholesterol concentration. Total and low density lipoprotein cholesterol concentrations were higher in the meat eaters than in all other groups. Concentrations in the vegans were significantly lower than those in vegetarians and fish eaters, who had similar values. High density lipoprotein cholesterol concentrations were significantly higher in the fish eaters compared with the three other diet groups. The figure shows the effects of age and sex on these lipid concentrations in the four dietary groups. Table IV summarises the significance of the influence of the various factors on the cholesterol concentrations. The p values quoted apply to tests of heterogeneity, and thus for the row labelled diet the test was of differences between all four diets. For the row labelled, for instance, age×sex the test was for an interaction of age with sex after adjustment for age and sex separately; thus the test was for a different effect of age between the sexes. For most groups there was a characteristic increase with age in concentrations of total and low density lipoprotein cholesterol: women tended to show a continuous increase with age, whereas concentrations in men did not increase appreciably after the age of 40. In younger age groups men had higher concentrations than women, whereas in the older groups this



Mean cholesterol concentrations in men and women.

TABLE IV—*Significance of effect of each factor on concentrations of total cholesterol, low density lipoprotein cholesterol, and high density lipoprotein cholesterol and ratio of low density lipoprotein cholesterol concentration to high density lipoprotein cholesterol concentration*

Factor	df	F Value (p)			
		Total cholesterol	Low density lipoprotein cholesterol	High density lipoprotein cholesterol	Low density lipoprotein cholesterol:high density lipoprotein cholesterol
Age	4,3272	148·7 (p<0·001)	121·6 (p<0·001)	0·47 (NS)	67·32 (p<0·001)
Sex	1,3271	0·32 (NS)	0·04 (NS)	356·2 (p<0·001)	136·59 (p<0·001)
Age×sex	4,3267	11·4 (p<0·001)	10·6 (p<0·001)	2·57 (p<0·05)	3·48 (p<0·01)
Diet	3,3264	55·7 (p<0·001)	54·7 (p<0·001)	3·80 (p<0·01)	39·15 (p<0·001)
Age×sex×diet	27,3237	0·94 (NS)	0·53 (NS)	0·66 (NS)	1·05 (NS)

Statistical methods—Ages were categorised into five groups for statistical analyses: 29 and less, 30-39, 40-49, 50-59, and 60 and over. Age, sex, and diet (four groups) were fitted into a linear model successively with interactions after the main effects of each factor.[12] Thus for total, low density lipoprotein, and high density lipoprotein cholesterol concentrations and the ratio of low density lipoprotein to high density lipoprotein cholesterol concentration the effects of age, sex, and their interaction were fitted first. Then an independent (that is, standardised for age and sex) effect of diet on these values was fitted and tested. Finally, we fitted a full model to test for an effect of diet on the age and sex relation. Preliminary examinations of the data indicated that the lipid concentrations were more nearly Gaussian after a logarithmic transformation,[13] and therefore all significance tests were conducted with logarithmic transformations.

difference was reversed, resulting in similar mean concentrations for men and women overall. On the other hand, high density lipoprotein cholesterol concentrations were higher in women (mean 1·72 mmol/l) than men (1·47 mmol/l) but did not show any trends with age. Despite the profound differences in concentrations of total and low density lipoprotein cholesterol among the diet groups, diet did not have a significant influence on the effects of age and sex described above. In vegan men there did not seem to be any increase up to the age of 60, but the numbers in each age group were small and insufficient for us to be certain.

Discussion

Rural Africans, Asians, and other people whose diets are low in saturated fat and animal protein and high in complex carbohydrate have low blood cholesterol concentrations and prevalences of coronary heart disease.[14] Mediterranean populations also have lower cholesterol concentrations and prevalences of coronary heart disease than those in Britain, perhaps because their diet is high in monounsaturated and polyunsaturated fatty acids.[1,15] Although various dietary manipulations (reducing saturated fat intake, increasing the ratio of polyunsaturated or monounsaturated fatty acid intake to saturated fatty acid intake, or increasing intake of soluble fibre) can reduce blood cholesterol concentrations,[16] relatively few studies have shown an association between dietary characteristics and lipid concentrations within populations.[3] Shekelle *et al*, however, found a relation between blood cholesterol concentration and the ratio of polyunsaturated fatty acid intake to saturated fatty acid intake; various dietary scores that described fat intake were also related to cholesterol concentrations.[17]

Our data confirm the findings of several other studies that lower concentrations of total and low density lipoprotein cholesterol are found in vegetarians than in meat eaters.[4-6] In addition, we showed that those who regularly ate fish (but no meat) had concentrations similar to those in vegetarians and that vegans had lower concentrations than those in any of the other dietary groups. These differences were not explained by differences in the age and sex structures of the groups. Apart from the obvious differences in intakes of animal protein, vegetarians and vegans have higher intakes of dietary fibre and total carbohydrate and a higher ratio of polyunsaturated fatty acid intake to saturated fatty acid intake than meat eaters. The participants in this study were volunteers who agreed to complete a dietary questionnaire and give a blood sample; such people are not necessarily representative of the dietary groups from which they are drawn. In particular, the meat eaters used alcohol and tobacco less than the general population and may well also have had a healthier diet; this, however, would probably have reduced rather than increased the differences in blood lipid concentrations among the diet groups. All these dietary characteristics may contribute to the low concentrations of total and low density lipoprotein cholesterol, which might, in turn, partly explain the reduced standardised mortality ratios for coronary heart disease observed in American[7] and Dutch[8] Seventh Day Adventists (most of whom are vegetarian) and British vegetarians.[9]

High concentrations of high density lipoprotein cholesterol may help to protect some people in high risk populations against coronary heart disease, although data from the British regional heart study have not shown high density lipoprotein cholesterol concentration to be an independent risk factor for ischaemic heart disease.[18] The finding of similar concentrations in vegans, vegetarians, and meat eaters suggests that high concentrations of high density lipoprotein cholesterol might be less important when concentrations of low density lipoprotein cholesterol are low. Kromhout *et al* showed an inverse relation between risk of coronary heart disease and the amount of fish eaten[10]; the higher concentration of high density lipoprotein cholesterol that we found in fish eaters might partly account for this.

Blood cholesterol concentration has been shown to increase with age in several studies carried out in affluent societies. The size of the groups in this study allowed, for the first time, the effects of age and sex on concentrations of total and low density lipoprotein cholesterol in different dietary groups to be examined. In the younger age groups women had lower concentrations than men. In all dietary groups, however, women showed a steep and continuous rise with age up to the age of 60, whereas concentrations in men did not increase appreciably after the age of 40, so that after 50 concentrations were higher in women than men in all groups. Whether this was a cohort effect as opposed to a physiological effect of age is difficult to determine in a single cross sectional study. This sex difference, which has also been shown in other studies,[19] may in part be due to the change in hormonal state at the time of the menopause, although the study by McPherson *et al* found no difference between premenopausal and postmenopausal women of similar age.[20] Miller suggested that a defect in activity of the low density lipoprotein receptor acquired in healthy subjects during aging may contribute substantially to the incidence of coronary heart disease.[21] This does not, however, account for the sex differences we observed, which may partly explain the sharp increase in the incidence of coronary heart disease in women after the menopause.

Recent data have suggested that a 10% reduction in cholesterol concentration might be associated with a 30% reduction in the incidence of coronary heart disease.[2] Our data suggest that in Britain the incidence of coronary heart disease may be 24% lower in lifelong vegetarians and 57% lower in lifelong vegans than in meat eaters. Follow up of the groups we studied may confirm this, as well as providing an opportunity of studying further the relation between low cholesterol concentrations and the incidence of cancer.

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