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Dietary and other determinants of lipoprotein levels within a population of 315 Dutch males aged 28 and 29

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The objective of this study was to estimate the strength of the association between diet and serum lipids and lipoproteins within a free-living population. Three hundred and fifteen Dutch males aged 28 and 29 were located via the Army registry. Their diets were assessed through a dietary history questionnaire plus oral cross-check, and blood was sampled twice at a 1-week interval. Height, weight, skinfolds, and waist and hip circumference were measured to estimate amount and location of body fat. Physical activity, social status and smoking were estimated through questionnaires. The range of cholesterol values predicted from differences in dietary fatty acid and cholesterol intake as summarized by the Keys equation score was 5.11 to 6.29 mmol/l, while the actual levels ranged from 3.30 to 9.28 mmol/l. Multiple regression analysis showed a weak but significant association of the Keys score with total cholesterol (slope 0.83, $P < 0.05$), *LDL* cholesterol (slope 0.71, $P < 0.05$), and the HDL/total cholesterol ratio (slope -0.04, $P < 0.01$). The percentage of energy from alcohol was strongly and independently associated with both total and HDL cholesterol (slopes 0.04 and 0.02, $P < 0.001$). Body fat parameters were strongly associated with all serum lipids and lipoproteins. We conclude that the contribution of dietary differences to differences in serum lipids and lipoproteins within this population is real but small.

A high concentration of serum total cholesterol and a low concentration of high density lipoprotein (HDL) cholesterol are both associated with a high risk for coronary heart disease (Miller & Miller, 1975; Kannel *et al.*, 1971). In experimental studies increased intakes of saturated fat and cholesterol (Keys, 1984; Beynen & Katan, 1989; Brussaard *et al.*, 1980) consistently cause higher levels of serum cholesterol. Between populations there is also a clear relation between diet and serum total cholesterol levels in both children and adults (Knuiman *et al.*, 1983; Keys, 1970). The relation between habitual diet and serum cholesterol is much less evident at the level of the individual within populations, although significant but low correlations have been found in a number of studies (Crawford *et al.*, 1981; Easty, 1970; Garcia-Palmieri *et al.*, 1977; Jacobson & Thelle, 1987; Kay, Sabry & Csima, 1980; Kesteloot, Gebroers & Pietinen, 1987; Knuiman *et al.*, 1983; Nichols *et al.*, 1976; Niessen, Brussaard & Katan, 1983; Shekelle *et al.*, 1981). Apart from genetic differences, differences in age (Berns, de Vries & Katan, 1989), body fatness (Foster *et al.*, 1987; Laskarzewski *et al.*, 1980), socioeconomic status (Holme *et al.*, 1976; Kraus, Borhani & Franti, 1980),

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physical activity (Folsom *et al.*, 1985; Stulb *et al.*, 1965), and smoking habits (Garrison *et al.*, 1978; Stamford *et al.*, 1984) may obscure the effect of diet at the individual level. However, imprecision of dietary survey methods appears to be the major reason why some investigators have failed to find significant relations between dietary lipids and serum cholesterol within populations (Beaton *et al.*, 1979; Jacobs, Anderson & Blackburn, 1979; Keys, 1965; Liu *et al.*, 1978).

Experimentally, the major dietary influences on HDL cholesterol levels appear to be alcohol consumption and the intake of carbohydrates and cholesterol (Beynen & Katan, 1985; Burr *et al.*, 1986; Criqui *et al.*, 1983; Schonfeld *et al.*, 1976). These relations have been confirmed in epidemiological studies within populations (Dhiel *et al.*, 1988; Ernst *et al.*, 1980; Fehily *et al.*, 1988; Frank, Berenson & Webber, 1978; Heiss *et al.*, 1980; Jacqueson *et al.*, 1983), but have not been obvious in ecological comparisons of population means; in the latter type of study, only the dietary fat/carbohydrate ratio in children has been consistently and strongly associated with the HDL cholesterol level (Knuiman *et al.*, 1987).

Thus it is not yet clear to what extent differences between individuals in serum total and HDL cholesterol levels can be explained by differences in the composition of self-selected diets. In this report we present a multivariate study of the relation between serum lipoproteins and dietary and other determinants in a homogeneous population of 28- to 29-year-old males.

Subjects and methods

The participants in this study were 315 men aged 28 or 29 who were seen in 1986 as a part of a longitudinal study on determinants of the rise of cholesterol with age (Berns *et al.*, 1989). They had been seen for the first time when they were examined for their fitness for military service at the age of 18 or 19, and were located for the present study via the Army registry (Berns *et al.*, 1989). The men selected for follow-up were limited to those who had a reported change in body mass index over the past 10 years below the 25th or above the 75th percentile of the original study population.

The study was carried out using the outpatient clinic facilities of six hospitals located in the middle region of the Netherlands. Each subject was seen twice, at an interval of about 1 week. The measurements were done by four well-trained M.Sc. students of our department together with two of the authors (M.A.M.B. and J.H.M.dV.). The study was approved by the Human Ethics Committee of the Department, and all participants gave their prior written informed consent.

Anthropometric measurements

At both visits body weight and height were measured while the subjects were in their underwear. At the first visit the thickness of the tricipitalis (back of upper arm), bicipitalis (front of upper arm), subscapula (back, below shoulder blade), supra-iliaca (side, just above hipbone) and para-umbilicalis (beside the navel) skinfolds was measured in triplicate with a Harpenden skinfold caliper. For the estimation of the body fat percentage the sum of the tricipitalis, bicipitalis, supra-iliaca and the subscapular skinfolds was used (Durnin & Wormersley, 1974). Waist and hip circumference were measured in duplicate with a measuring tape. The amount of fat within the abdominal cavity was estimated using the following equation (Seidell *et al.*, 1987):

$$\text{Area of intra-abdominal fat (cm}^2\text{)} = -37.322 + 0.350 \times (\text{body mass index}) + 0.405 \times \sqrt{(\text{paraumbilicus} + \text{suprailiaca})} + 33.118 \times \sqrt{(\text{waist/hip ratio})} + 0.068 \times \text{age}^2.$$

Smoking habits, physical activity, and socioeconomic status

At the first visit the participants were given a questionnaire about smoking habits (Berns *et al.*, 1989), physical activity (Baecke, Burema & Freyters, 1982) and socioeconomic status (Westerlaak, Kropman & Collaris, 1975). The socioeconomic status of the participants was derived from their occupation and level of education, and was scored as one of three categories: 1 (low), 2 (middle), and 3 (high) (Westerlaak *et al.*, 1975). Three dimensions of habitual physical activity were estimated: physical activity at

work, sports activities during leisure time, and other physical activities during leisure time. Each dimension of habitual physical activity was coded on a scale ranging from one (low) to five (high) (Baecke *et al.*, 1982).

Dietary habits

The dietary method applied was essentially a dietary history with cross-check (Bingham *et al.*, 1988). At the first visit the participants received a questionnaire containing detailed questions on their habitual diet during week days. At the second visit 1 week later, the subjects handed in their written answers which were then discussed with them question by question. Following this, subjects were asked about the frequency with which they consumed each of 88 items specified in a food frequency list. This served both to check the dietary history questionnaire, and to collect data for foods eaten during the weekend. Intake data were coded and nutrient content calculated using the 1983 release of the national Dutch nutrient data base (UCV) (Hautvast, 1975).

The dietary lipid score of Keys *et al.* (Keys, Anderson & Grande, 1965*a*) was calculated as:

$$\text{Keys score (mmol/l)} = [168 + 1.35 \times (2S - P) + 1.5 \times \text{chol}]/38.7$$

Here S is the percentage of daily energy intake contributed by saturated fatty acids, P the percentage of energy from polyunsaturated fatty acids, and chol the intake of cholesterol in mg per 1000 kcal. A high Keys score indicates a high intake of saturated fatty acids and cholesterol and a low intake of polyunsaturated fatty acids.

Blood sampling and analysis

At both visits non-fasting blood was sampled using evacuated tubes as described by Berns *et al.* (1989). Serum samples were stored at the hospital at −20 °C and transported once a week in the frozen state to Wageningen where they were stored at −80 °C until analysis. Sera were analysed for total and HDL cholesterol and triglycerides, using enzymatic methods and strict quality control (Katan *et al.*, 1982; Rosschlau, Bernt & Gruber, 1974; Sullivan *et al.*, 1985; Warnick, Benderson & Albers, 1982). Samples were analysed in random order. The combined within and between run coefficient of variation for control sera was 0.8 per cent for total and 1.7 per cent for HDL cholesterol, and 0.3 per cent for total triglycerides. Accuracy was checked by analysis of serum pools of known value provided by the Centers for Disease Control (CDC; Atlanta, GA). Mean bias with regard to CDC target values was −0.7 per cent for total cholesterol, −4.4 per cent for HDL cholesterol and 0.9 per cent for total triglycerides. The LDL cholesterol concentration was calculated using the Friedewald equation (Friedewald, Levy & Fredrickson, 1972). This has been shown to be valid for non-fasting sera, provided that the triglyceride concentration does not exceed 8 mmol/l (Demacker *et al.*, 1984).

Statistics

The serum lipid and lipoprotein concentrations were the dependent variables to be explained in the statistical analyses. We investigated the following explanatory variables: body mass index (BMI), body fat percentage as calculated from skinfolds, ratio of waist-to-hip circumference, ratio of subscapular to triceps skinfold thickness, the area of intra-abdominal fat, socio-economic status, physical activity, intake of various nutrients, and smoking habits. Interrelations between explanatory variables were explored by calculating Pearson product-moment correlations. Associations of serum lipids and lipoproteins with explanatory variables were first analysed by univariate regression analysis. Variables showing significant associations were then entered into a stepwise multiple regression analysis (SPSS-X Basics, 1984).

Results

Table 1 presents the characteristics of the 315 subjects. As argued elsewhere (Berns *et al.*, 1989) these men were reasonably representative of Dutch men in this age group, except that men who had experienced an intermediate rise in body weight over the previous 10 years were underrepresented.

Table 1. Characteristics and diet composition of 315 Dutch men aged 28–29 years in 1986.

Characteristic	*Mean*	*s.d.*	*Range*
Height (cm)	181.1	6.6	158.6–206.5
Weight (kg)	77.2	11.7	49.2–124.0
Body mass index (kg/m^2)	23.5	3.1	17.0–34.8
Body fat percentage (g/100 g body wt)[a]	17.4	4.8	6.4–29.1
Subscapular/triceps skinfolds ratio	1.14	0.32	0.53–2.63
Waist/hip circumference ratio	0.97	0.04	0.85–1.11
Area of intra-abdominal fat (cm^2)[b]	64.5	31.1	12.4–173.1
Physical activity (arbitrary units, from 1 to 5)			
Work	2.7	0.8	1.1–4.5
Sports	2.6	0.8	1.0–4.8
Leisure time	2.6	0.6	1.0–4.5
Number of cigarettes/day[c]	15.6	1.4	1–40
Socioeconomic status (% in each category)			
low	31		
middle	48		
high	21		
Serum cholesterol concentration			
Total (mmol/l)[d]	5.43	1.06	3.30–9.28
HDL (mmol/l/[d]	1.18	0.26	0.66–2.07
LDL (mmol/l)[d]	3.51	0.91	1.54–6.60
Ratio HDL/total cholesterol	0.23	0.07	0.09–0.48
Triglycerides (mmol/l)[d]	1.63	0.90	0.36–5.54
Habitual diet			
Energy (MJ/d)	13.7	3.5	6.6–31.1
(kcal/d)	3282	847	1571–7442
Protein (% of energy)	13.5	2.1	8.1–21.3
Fat (% of energy)	39.2	5.5	22.6–57.9
Saturated (% of energy)	15.5	2.4	9.2–22.0
Polyunsaturated (% of energy)	6.7	1.9	2.8–14.2
Carbohydrates (% of energy)	43.3	5.7	25.0–64.6
Alcohol (% of energy)	5.0	4.5	0.0–31.9
Cholesterol (mg/MJ)	30.7	7.0	12.9–64.5
(mg/1000 kal)	128	29	54–270
Keys score (mmol/l)[d,e]	5.63	0.20	5.11–6.29

[a] As calculated from the sum of skinfold thicknesses (Durnin & Womersley, 1974).
[b] See Seidell *et al.*, 1987.
[c] For those subjects who smoked (40 per cent of all subjects).
[d] To convert to mg/dl, multiply by 38.7 for cholesterol and by 88.5 for triglycerides.
[e] The Keys score predicts the serum cholesterol concentration as the sum of a constant term plus terms for the intake of saturated fatty acids, polyunsaturated fatty acids, and cholesterol (cf. Methods).

In Table 2 univariate regression coefficients of serum lipids and lipoproteins on various explanatory variables are presented. The Keys score of dietary fatty acid and cholesterol intake, which predicts the composite effect of dietary lipid intake on serum cholesterol level, was significantly and positively related with serum total cholesterol, triglyceride and LDL cholesterol levels. The product-moment (Pearson) correlation coefficient between the Keys score and the serum total cholesterol level was 0.13 ($P = 0.02$). For alcohol intake we found a positive relation with HDL cholesterol and with trigylcerides. In univariate analysis total cholesterol, triglycerides and LDL cholesterol were also positively related with BMI, body fat percentage, waist-to-hip ratio, and the area of intra-abdominal fat, whereas the HDL cholesterol level and the ratio of HDL to total cholesterol were negatively related with these body fatness indicators. In contrast to the waist/hip ratio, the ratio of the subscapular to triceps skinfold showed weak but negative relations with cholesterol, triglycerides, and LDL cholesterol. In those subjects who smoked, total cholesterol, LDL cholesterol and tri-

Table 2. Univariate regression coefficients of various explanatory variables on serum lipids and lipoproteins in 315 Dutch men aged 28 and 29 in 1986.

	Dependent variable									
	Serum cholesterol (mmol/l)[a]		*HDL-cholesterol (mmol/l)*[a]		*LDL-cholesterol (mmol/l)*[a]		*HDL/total cholesterol ratio*		*Triglycerides (mmol/l)*[a]	
Explanatory variable	*b*	*SE*	*b*	*SE*	*b*	*SE*	*b*	*SE*	*b*	*SE*
Body mass index (kg/m^2)	0.133***	0.018	−0.023***	0.004	0.103***	0.015	−0.009***	0.001	0.116***	0.015
Body fat (g/100 g body wt)	0.096***	0.011	−0.018***	0.003	0.075***	0.010	0.007***	0.001	0.086***	0.009
Subscapular/triceps ratio	−0.505***	0.187	0.026	0.046	−0.380*	0.160	0.026*	0.011	−0.329*	0.158
Waist/hip ratio	9.076***	1.484	−1.459**	0.370	6.458***	1.287	0.586***	0.090	8.917***	1.217
Cigarettes (number/d)	0.014*	0.006	−0.004*	0.002	0.012*	0.005	−0.001*	0.000	0.014*	0.005
Physical activity (1 to 5)	−0.045	0.048	0.009	0.012	−0.024	0.041	0.003	0.003	−0.066	0.040
Keys score (mmol/l)	0.690*	0.301	−0.087	0.073	0.736*	0.256	−0.049*	0.018	0.089	0.255
Alcohol (energy %)	0.058***	0.013	0.011**	0.003	0.030**	0.011	−0.000	0.001	0.037**	0.011
Socioeconomic status (1 to 3)	0.003	0.085	0.036	0.020	−0.023	0.072	0.006	0.005	−0.021	0.071
Intra-abdominal fat (cm^2)	0.014***	0.002	−0.002***	0.001	0.011***	0.002	0.001***	0.000	0.013***	0.001

Significantly different from 0: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

[a] To express regression coefficient in mg/dl, multiply by 38.7 for cholesterol and by 88.5 for triglycerides.

Table 3. Stepwise multiple regression analysis using as dependent variables the serum lipid and lipoprotein concentrations, and as independent variables body fatness indices, dietary factors, number of cigarettes, and leisure time activity index.

	Dependent variable									
Independent variables with a significant contribution	*Total cholesterol (mmol/l)*[a]		*HDL-cholesterol (mmol/l)*[a]		*LDL-cholesterol (mmol/l)*[a]		*HDL/total cholesterol ratio*		*Triglycerides (mmol/l)*[a]	
	b	*SE*	*b*	*SE*	*b*	*SE*	*b*	*SE*	*b*	*SE*
Body fat percentage (g/100 g body wt)	0.09***	0.01	−0.02***	0.00	0.07***	0.01	−0.01***	0.00	0.10***	0.01
Alcohol (energy %)	0.04***	0.01	0.02***	0.00						
Keys score (mmol/l)	0.83*	0.27			0.71*	0.24	−0.04*	0.01		
Cigarettes smoked (no./day)			−0.01***	0.00	0.01*	0.01	−0.001*	0.000		
Subscapular/triceps ratio			−0.12*	0.05			−0.03*	0.01	0.036*	0.15
Constant (mmol/l)[b]	−1.07	1.55	1.67	0.09	−1.86	1.34	0.63	0.09	−0.48	0.30

Significantly different from 0: * $P < 0.05$, *** $P < 0.001$.

[a] To express regression coefficient in mg/dl, multiply by 38.7 for cholesterol and by 88.5 for triglycerides.

[b] HDL/total cholesterol: (mmol/mmol). Note that the Keys score contains an additional constant term of 4.34.

glycerides went up and the HDL cholesterol and HDL to total cholesterol ratio went down with the number of cigarettes smoked per day. Total cholesterol, triglycerides, and LDL cholesterol were lower, and HDL cholesterol was higher in subjects with a high habitual physical activity during leisure time.

Except for the subscapular to triceps skinfold ratio, all body fatness variables were positively correlated with each other; product-moment correlation coefficients ranged from $r = 0.61$ for the correlation of the waist-to-hip circumference with body fat percentage, to $r = 0.94$ for the correlation of BMI with the area of intra-abominal fat. There were also interrelations of each of the three dimensions of physical activity with the smoking habits, with r-values ranging from -0.14 for physical activity during leisure time to 0.16 for physical activity at work. A higher socioeconomic status was accompanied by lower indices of body fatness, with r ranging from -0.17 for the relation between socioeconomic status and the ratio of waist-to-hip circumference, to 0.01 for the relation between socioeconomic status and the ratio of subscapular to triceps skinfold thickness. Alcohol intake was positively related to all indices of body fatness ($r = 0.14$ to 0.18) except for the relation with the subscapular to triceps skinfolds ($r = -0.11$).

In the multiple regression analysis (Table 3) differences in the intake of dietary fatty acids and cholesterol as summarized in the Keys score made a significant contribution to differences in total and LDL cholesterol levels. Of the anthropometric measurements, only the body fat percentage estimated from skinfolds contributed significantly towards explanation of lipid and lipoprotein levels. The ratio of the subscapular to the triceps skinfold thickness made an independent contribution towards explaining variance in HDL cholesterol, triglycerides and the ratio of HDL to total cholesterol. Two dietary variables – the Keys score for fatty acid plus cholesterol intake, and the intake of alcohol – together explained 9 per cent of the variance in serum total cholesterol levels. When body fatness and smoking were added as explanatory variables, the proportion of variance explained rose to 24 per cent. Body fat percentage, the subscapular to triceps ratio, alcohol and the number of cigarettes smoked together explained 23 per cent of the variance in HDL cholesterol, whereas alcohol intake alone explained 6 per cent of the variance in HDL cholesterol. The Keys dietary lipid score plus two parameters for body fatness, body fat percentage and the subscapular to triceps ratio, together explained 30 per cent of the variance between subjects in the ratio of HDL to total cholesterol. Only 2 per cent of the variance in this ratio could be explained by the Keys score for dietary lipid intake.

Discussion

Although the men studied by us constituted a fairly homogeneous group, differences in serum lipids and lipoproteins were significantly associated with differences in the self-selected diet. The 'old' Keys equation (Keys, Anderson & Grande, 1957) which we used to summarize the effects of dietary lipids on total cholesterol treated all the saturated fatty acids together. As stearic acid does not raise cholesterol, it would have been more appropriate to use Keys' equation in its more definitive form (Keys, Anderson & Grande, 1965*b*). We used the 'old' equation because reliable data on separate fatty acids in foods were not available in our data base. However, as the ratio of cholesterol-raising to total saturated fatty acids is fairly constant (Paul, Southgate & Russel, 1980), switching equations would have affected the numerical value of the regression coefficient but not the significance.

When the Keys score and the alcohol intake were used as the sole independent variables, the percentage of variance explained by diet in our study ranged from 2 per cent for the HDL cholesterol/total cholesterol ratio to 9 per cent for total cholesterol. This value is of the same order of magnitude as that found in studies within other populations, as reviewed in Table 4. In most of those studies including ours, the estimate of the proportion of variance due to diet is probably biased downwards by the

Subjects	Number (n)	Dietary components	Strength of association r	Slope[a] mmol/l	mg/dl	P	Reference
Healthy men (28–29 years)	315	Keys score	0.13	0.87	0.87	<0.05	This study
		% of energy from alcohol	0.24	0.04	1.55	<0.001	
Men (20–60 years)	119	Cholesterol (mg/1000 kcal)	−0.02			n.s.	Keys *et al.* (1956)
Young male adults (22–34 years)	24	% of energy from fat	0.49			<0.05	Easty (1970)
Men (20–69 years) Tecumseh study	1624	Fat	−0.11			<0.001	Nichols *et al.* (1976)
		Alcohol	−0.03			n.s.	
Rural Puerto Rican men	1225	Energy % fat		0.0002	0.01	n.s.	Garcia-Palmieri *et al.* (1977)
(45–54 years)		Energy % saturated fat		0.011	0.41	n.s.	
		Energy % polyunsaturated fat		−0.023	−0.88	<0.05	
		Cholesterol		0.000	0.00	n.s.	
Urban Puerto Rican men	3418	Energy % fat		0.012	0.45	n.s.	
(45–54 years)		Energy % saturated fat		0.029	1.14	<0.05	
		Energy % polyunsaturated fat		0.001	0.04	n.s.	
		Cholesterol		0.0003	0.01	<0.05	
Children (10 years)	185	Saturated fat per 1000 kcal	—			n.s.	Frank, Berenson & Webber (1978)
The Bogalusa Heart Study		Polyunsaturated fat per 1000 kcal	—			n.s.	
		Cholesterol	—			n.s.	
Dutch students (17–30 years)	371	Keys score	0.14			<0.05	Niessen, Brussaard & Katan (1983)
Children (6–19 years)	1457	Saturated fat	0.01[b]			n.s.	Morrison *et al.* (1980)
Cincinnati Lipid Research		Polyunsaturated fat	−0.03[b]			n.s.	
Clinic		Cholesterol	0.02[b]			n.s.	
Canadian men (35–39 years)	200	Energy % fat	0.19			<0.01	Kay *et al.* (1980)
Children (6 years)	84	Energy % fat	0.18			<0.05	Crawford *et al.* (1981)
		Energy % saturated fat	0.11			n.s.	
		Cholesterol	0.45			<0.01	
Men in Chicago (40–55 years)	1900	Keys score		0.54	0.54	<0.001	Shekelle *et al.* (1981)
White males (20–59 years)	2269	Energy % fat	0.04			<0.05	Gordon *et al.* (1982)
		Energy % saturated fat	0.04			n.s.	
		Cholesterol (mg/1000 kcal)	0.03			n.s.	
		Energy % alcohol	0.07			n.s.	
Dutch boys[c]	117	Energy % fat	0.26			<0.01	Knuiman *et al.* (1983)
(7–10 years)		Energy % saturated fat	0.26			<0.01	
		Energy % polyunsaturated fat	0.10			n.s.	
		Cholesterol (mg/1000 kcal)	0.23			<0.01	
Healthy men (30–55 years)	77	Saturated fat	−0.05[d]			n.s.	Williams *et al.* (1986)
		Polyunsaturated fat	−0.29[d]			<0.01	
Belgian men (all ages)	15 954	Log (saturated fat)		0.41	16.16	<0.01	Kesteloot *et al.* (1987)
		Log (polyunsaturated fat)		−0.20	−7.56	<0.01	

[a] Regression coefficients in linear multiple regression analysis.
[b] Partial correlation coefficients adjusted for anthropometric and demographic variables (age, sex, race, weight, height, Quetelet-index).
[c] In this study of boys in five countries significant Pearson correlations were also found between percentage of energy from fat and serum total cholesterol in the Philippines, between serum total cholesterol and energy from saturated fatty acids in Finland, Italy and the Philippines, between percentage of energy from polyunsaturated fatty acids and serum total cholesterol in the Philippines and Ghana, and between serum total cholesterol and dietary cholesterol per 1000 kcal in Finland.
[d] Spearman's correlation coefficient.

imprecision of dietary surveys methods (Lozy, 1983; Marr, 1971; Sempos *et al.*, 1985). On the other hand we may have missed a number of studies, either published or unpublished, that found no relation at all. The sum of the evidence appears to indicate that those dietary factors that affect total cholesterol in controlled trials explain a significant but small proportion of the variance in total cholesterol levels found within populations. Thus the within-population studies by and large tend to agree with the evidence from trials (Beynen & Katan, 1989) and from 'ecological' comparisons of population means (Keys, 1970), which showed that diets high in saturated fat and cholesterol raise serum total cholesterol levels. However, the range in total cholesterol levels observed within populations is much larger than that expected from the rather modest differences in long-term dietary habits.

In our study, the range of intakes of fatty acids and cholesterol when summarized in the form of the Keys score led to a predicted range of cholesterol values from a minimum of 5.11 to a maximum of 6.29 mmol/l (198 to 243 mg/dl). However, actual cholesterol values ranged from 3.30 to 9.28 mmol/l (128 to 359 mg/dl). Therefore, other environmental and genetic factors are evidently major additional causes of variation in total cholesterol and thus also of each individual's position within the distribution of cholesterol values.

As LDL carries the major part of cholesterol in plasma, genetic and environmental modulators of LDL production and catabolism must be responsible for most of the variance in cholesterol levels within populations. A number of genetic polymorphisms are now known to influence LDL cholesterol levels within populations. Mutations in the apoE and apoB apolipoproteins inhibiting the binding of triglyceride- or cholesterol-rich lipoproteins by their receptors are now known to be responsible for an appreciable proportion of the variance in cholesterol levels within populations (Ehnholm *et al.*, 1986; Talmud *et al.*, 1987; Tikkanen *et al.*, 1988).

In the present cross-sectional analysis body fatness was also strongly associated with serum lipid and lipoprotein levels. Although the bimodal distribution of BMI values in our sample may have somewhat inflated the significance levels, obesity is undoubtedly a major determinant of serum lipoprotein levels within populations. Thus the relative contributions of various nutrients to energy intake, plus the accumulation of body fat caused by excess of energy intake might together still make diet a major determinant of differences in lipid levels within a population.

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