Dietary fat intake in healthy adolescents: inverse relationships between the estimated intake of saturated fatty acids and serum cholesterol

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The objective of the present study was to describe the intake of dietary fatty acids among healthy 15-year-old boys and girls and to relate the intake of specific fatty acids and the fatty acid composition of the serum cholesterol esters to serum lipid, apolipoprotein (Apo) and insulin concentrations respectively. Fifty-two girls and forty-two boys were randomly selected from the official population register. Unexpectedly, significant inverse associations were found between the dietary content of saturated fatty acids with a chain length of four to fifteen C atoms, mainly derived from milk fat, as well as the corresponding fatty acids in the serum cholesterol esters, on the one hand and the serum concentrations of cholesterol and ApoB on the other. The estimated dietary intake of 4:0–10:0, 12:0 and 14:0 respectively, were all significantly inversely related to the serum cholesterol (r −0·32, r −0·31, r −0·30, all $P < 0.05$) and ApoB (r −0·42, r −0·42, and r −0·40, all $P < 0.05$) concentrations in girls and 12:0 to the ApoB concentration (r −0·55, $P < 0.01$) in boys. The proportions of 12:0 and 15:0 in the serum cholesterol esters were negatively correlated with the serum cholesterol concentrations in both girls (r −0·34, r −0·32, $P < 0.05$) and boys (r −0·53, $P < 0.01$; r −0·32, $P < 0.05$) and with the ApoB concentrations among boys (r −0·61, $P < 0.01$; r −0·43, $P < 0.05$). It is conceivable that milk fat contains or is associated with some component in the diet, or some other characteristics of the food intake, which counterbalances the expected positive relationships between saturated fat intake and lipid levels.

Milk fat: Fatty acid composition: Serum lipids

Lifestyle factors, especially food habits, smoking and degree of physical activity are, in addition to genetic disposition, important determinants of health and disease. The food habits are probably to some extent established already in childhood and adolescence. Recently, two epidemiological studies have been conducted in Sweden aimed at establishing food habits and nutrient intake in adolescents (Bergström *et al.* 1993; Samuelson *et al.* 1996). By analysing the fatty acid composition in serum (Glatz *et al.* 1989; Ma *et al.* 1995; Nikkari *et al.* 1995) or adipose tissue (Field *et al.* 1985; van Staveren *et al.* 1986), it is possible to get additional information about the dietary fat quality, especially with regard to the intake of essential fatty acids.

The aim of the present study was to describe the intake of dietary fat among a group of randomly selected 15-year-old boys and girls and to relate the intake of specific fatty acids, and the fatty acid composition of the serum lipid esters to serum lipid, apolipoprotein (Apo) and insulin concentrations respectively, and also to the food sources from which the dietary fatty acids were derived. The intention was to investigate whether the existing dietary fat intake in this age group could be shown to be related to metabolic variables which have been indicated as risk factors for the development of CHD in adult populations.

Material and methods

The study was undertaken in the town of Trollhättan, Sweden, an industrial town with about 55 000 inhabitants. The study region and the population have been described in detail elsewhere (Samuelson *et al.* 1996).

From the official population register 259 healthy 15-year-old boys and girls were drawn at random. From this group, fifty-seven adolescents were excluded because they were not interested in taking part in the extensive longitudinal study. Thus, 202 adolescents took part in the nutritional survey. When the participants and the non-participants of the randomized sample were compared, no significant differences in the mean weights and heights

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either at birth or at the age of 15 years were found. In addition there were no differences in their socio-economic background, except regarding their mothers' education, which was higher in the study group ($P < 0.05$). In all other comparable aspects the participants and the non-participants were similar (Samuelson *et al.* 1996). The adolescents were all healthy at the time for medical examination and blood sampling. A subgroup of ninety-three adolescents, fifty-one girls and forty-two boys, were randomly selected for the present study. The anthropometric and clinical characteristics of this subgroup are very similar to those earlier described for the total group (Samuelson *et al.* 1996) indicating that the subsample studied here is representative of the whole group of participants. Some of the laboratory analyses could not be performed in all ninety-three subjects due to lack of sufficient amount of remaining serum. There was no systematic selection but the number of analyses performed in a subject was solely determined by the amount of serum available with the priority order: fatty acid composition, serum lipids, serum insulin, serum Apo. While serum fatty acids and lipid concentrations were analysed in virtually all, serum ApoA-I and ApoB could only be analysed in forty-nine (twenty-seven girls and twenty-seven boys) and fifty (twenty-eight girls, twenty-two boys) individuals respectively. There was no indication that these subjects differed from the others with regard to dietary habits or clinical characteristics.

The study was approved by the Ethic Research Committee of the Medical Faculties of the Universities of Uppsala and Gothenburg.

All the subjects were clinically examined by two paediatricians. Height was measured by a standardised wall measuring-stick and weight by a digital scale when the participants were only wearing light underwear.

Dietary assessment

One dietitian gave detailed instructions on how to record all food items eaten during one week, i.e. a 7 d record (Bingham, 1987). In their home the adolescents weighed their food using electronic scales (Soenhle, Mohardt, Germany), while for all other meals and between-meal eating and food eaten outside the home, food models were used as aids in determining the amounts consumed (Håglin *et al.* 1995). When the 7 d dietary record was validated by the doubly-labelled water method in a randomized subsample of fifty adolescents who participated in the present study (Bratteby *et al.* 1998), an underestimation of energy intake by approximately 20 % was found in accordance with reports by others. From the 7 d dietary records energy and nutrients were computed using the food database of the Swedish National Food Administration (report no. 14, Pc version, 1992; Uppsala, Sweden) which includes 1593 foods and dishes.

Physical activity

An activity diary was used to assess the total energy expenditure during the same 7 d as for the dietary recording. The adolescents scored their main daily activity during all 15 min periods of each day and scaled it in one of nine activity levels defined according to its energy cost (Bratteby *et al.* 1997b). In a validation study in a subgroup of adolescents using the doubly-labelled water method, the activity diary provided close estimates of total energy expenditure on a group basis (Bratteby *et al.* 1997a).

Blood sampling and chemical analyses

The blood samples were collected after an overnight fast. After centrifugation the sera were collected and stored at $-70°C$ until analysed. Triacylglycerol and cholesterol concentrations were measured in serum by enzymatic methods, using the IL Test Cholesterol Triander's method 181618–80 and the IL Test Enzymatic-Colorimetric-Method 1811709–00 for use in Monarch apparatus (Instrumentation Laboratory, Lexington, MA, USA). The concentrations of serum ApoB and ApoA-I were determined by immunoturbidimetry in a Monarch apparatus using monospecific polyclonal antibodies against ApoB and ApoA-I (Orion Diagnostic, Espoo, Finland). The samples were preincubated prior to the assay, as suggested by Da Col & Kostner (1983).

The fatty acid composition of the serum cholesterol esters was determined by GLC as described previously (Boberg *et al.* 1985). The serum insulin concentrations were measured by an ELISA test from Boehringer Mannheim GmbH (Mannheim, Germany).

Statistical methods

The results of this investigation were analysed using the software system Statistical Analysis System (SAS Institute Inc., Cary, NC, USA). For comparison of means between boys and girls the unpaired *t* test was used. Pairwise associations between variables were examined by Pearson product moment correlation analysis when the data were normally distributed. The triacylglycerol and insulin concentrations were logarithmically transformed before analysis by Pearson linear correlation. All other variables were normally distributed. Partial correlations were used when adjusting for BMI and physical activity to see if the relationships were still there after adjustment. Correlations with P values <0.1 are included in the tables. P values ≤ 0.05 or less are considered significant.

Results

Clinical characteristics

The mean body weight of the boys was significantly greater than that of the girls while the BMI was identical (Table 1). Three-quarters of the boys and almost all of the girls in the total sample had reached advanced puberty (Tanner stages 4 and 5; Tanner, 1962). The girls had on average higher serum cholesterol, serum ApoA-I and a tendency to higher ApoB concentrations, while there was no difference with regard to the serum triacylglycerols and the serum insulin concentrations.

Table 1. Clinical characteristics of subjects (Mean values and standard deviations for fifty-one girls and forty-two boys)

	Girls		Boys		Statistical significance of
	Mean	SD	Mean	SD	difference between boys and girls: P
Body weight (kg)	55·7	9·8	61·6	13·7	0·021
BMI (kg/m^2)	20·3	3·0	20·4	3·6	0·860
Serum triacylglycerol (mmol/l)	0·90	0·37	0·83	0·37	0·393
Serum cholesterol (mmol/l)	4·70	1·03	4·09	1·00	0·006
Serum insulin (mU/l)	11·0	3·6	10·8	4·3	0·855
Serum ApoA-I (g/l)*	1·30	0·20	1·13	0·13	0·002
Serum ApoB (g/l)†	0·71	0·16	0·63	0·14	0·080

* Girls n 27, boys n 22.
† Girls n 28, boys n 22.

Estimated dietary fat intake

The mean dietary intake and the average intake of dietary fatty acids (% energy), as calculated from the 7 d dietary records, are given in Tables 2 and 3. The proportion of energy derived from fat was slightly greater among the boys (NS). The dietary fat quality, as expressed by the relative proportions of the different fatty acids, was similar in boys and girls. The only difference was a slightly higher proportion of linoleic acid among the boys.

Fatty acid composition of the serum cholesterol esters

The fatty acid composition of the serum cholesterol esters was similar among the boys and the girls (Table 4). However, the boys had on average a somewhat greater proportion of palmitic (16:0) and stearic (18:0) acids while the girls had a greater proportion of palmitoleic (16:1n-7) acid in their cholesterol esters. The proportions of linoleic acid were identical in boys and girls.

Relationships between intake of fatty acids and fatty acid composition of the serum cholesterol esters

The relationships between the estimated proportions of specific fatty acids in the diet and the corresponding fatty

Table 2. Mean daily intake of energy, energy-yielding nutrients and dietary fibre*

(Mean values and standard deviations)

	Girls (n 51)		Boys (n 42)	
	Mean	SD	Mean	SD
Energy (kJ)	7318	1331	10347	2067
Energy (kcal)	1749	389	2473	494
Fat (g)	59	18	88	18
Fat (% energy)	30·4	5·2	32·1	3·8
Protein (g)	62	14	91	22
Protein (% energy)	14·2	2·1	14·7	2·1
Carbohydrates (g)	239	58	327	77
Carbohydrates (% energy)	54·8	5·0	52·8	4·4
Alcohol (g)	0·9	3·1	0·5	1·6
Alcohol (% energy)	0·3	1·1	0·1	0·4
Cholesterol (mg)	213	79	324	103
Fibre (g)	14·0	5·0	18·6	5·5

* Nutrient intake measured with a 7 d weighed record and analysed using the Swedish National Food Administration food database (report no. 14, Pc version, 1992; Uppsala, Sweden).

acids in serum were generally in the expected directions, although mostly not significantly so due to the rather small groups of subjects (data not shown).

Serum cholesterol ester fatty acid composition and the concentrations of serum lipids, apolipoproteins and insulin

Although the number of participants was relatively small, there were several significant associations between the proportions of different fatty acids in the serum cholesterol esters on the one hand and the metabolic variables on the other (Table 5, Fig. 1). A general pattern of negative correlations between the proportions of the saturated fatty acids with a chain length of twelve and fifteen C atoms, and the serum cholesterol, serum ApoB and serum ApoA-I concentrations respectively was found, with a negative correlation between the proportion of 15:0 and ApoB:ApoA-I in boys. In addition, there was a rather strong positive association between the proportion of palmitoleic acid in the cholesterol esters and the ApoB concentration in boys. Significant positive relationships were detected between the proportions of 14:0, 16:1 and 18:3n-6 in cholesterol esters and the serum triacylglycerol concentrations in girls.

While the proportion of linoleic acid was negatively related to the ApoB concentration in boys, there were positive relationships between the long-chain unsaturated n-6 fatty acids and serum cholesterol and the serum ApoB concentrations. Among the girls there was a significant positive relationship between the triacylglycerol concentrations and γ-linolenic acid (18:3n-6), while the dihomo-γ-linolenic (20:3n-6) and arachidonic (20:4n-6) acids were negatively related to the serum insulin concentrations.

All data given in Table 5 are adjusted by partial correlation for differences in BMI, as are the data presented in Table 6. However, the corresponding relationships were nearly identical before the adjustment for differences in BMI, as well as after adjustment for different degrees of physical activity.

Proportions of fat in the diet and serum lipids, apolipoproteins and insulin

When the proportions of dietary fatty acids, as estimated from dietary records and adjusted for energy intakes, were related to the metabolic variables (Table 6, Fig. 2), a

Table 3. Dietary fat intake (% energy)*

(Mean values and standard deviations)

	All (*n* 94)		Girls (*n* 51)		Boys (*n* 42)		Statistical significance of difference between boys and girls: *P*
	Mean	SD	Mean	SD	Mean	SD	
Total fat	31·1	4·7	30·4	5·2	32·1	3·8	0·083
Saturated	13·8	2·4	13·6	2·6	14·1	2·2	0·326
Monounsaturated	10·9	2·2	10·6	2·4	11·3	1·8	0·140
Polyunsaturated	4·2	1·0	4·1	1·1	4·4	0·7	0·013
4:0–10:0	1·2	0·4	1·2	0·4	1·2	0·4	0·963
12:0	0·7	0·2	0·7	0·2	0·7	0·2	0·786
14:0	1·5	0·4	1·5	0·4	1·5	0·3	0·736
16:0	6·7	1·1	6·6	1·2	6·9	1·0	0·153
16:1*n*-7	0·6	0·2	0·6	0·2	0·6	0·2	0·145
18:0	3·1	0·6	3·0	0·7	3·2	0·5	0·340
18:1*n*-9	9·8	2·0	9·6	2·2	10·1	1·7	0·175
18:2*n*-6	3·5	0·8	3·4	0·9	3·7	0·6	0·014
18:3*n*-3	0·5	0·1	0·5	0·2	0·5	0·1	0·439
20:0	0·1	0·03	0·1	0·04	0·1	0·03	0·443
20:4*n*-6	0·04	0·02	0·04	0·02	0·04	0·02	0·129
20:5*n*-3	0·01	0·01	0·01	0·01	0·01	0·01	0·159
22:5*n*-3	0·01	0·01	0·01	0·01	0·01	0·01	0·987
22:6*n*-3	0·04	0·03	0·04	0·03	0·04	0·03	0·337

* Nutrient intake measured with a 7 d weighed record and analysed using the Swedish National Food Administration food database (report no. 14, Pc version, 1992; Uppsala, Sweden).

picture emerged that in several aspects was similar to that described earlier. Thus, generally negative relationships between the intake of saturated fatty acids and serum lipid levels were found. This was true for the serum triacylglycerol in boys (with similar but not statistically significant associations in girls), the serum cholesterol in girls (with weak correlations in the same direction among the boys) and the serum ApoB concentrations among both sexes. Also, there were negative associations with the serum insulin concentrations in boys. On the other hand, with the exception of a negative relationship between the proportion of arachidonic acid and serum triacylglycerol in girls, all significant correlations between the proportions of long-chain *n*-6 and *n*-3 fatty acids and the serum lipid concentrations, were positive in both sexes.

Virtually identical data were achieved when the data for absolute intakes of the different fatty acids were used in the calculations, as well as when no adjustment for BMI was

undertaken. Thus, there were also significant negative relationships between the estimated absolute intakes of fatty acids with chain length four to ten, twelve and fourteen, and both serum cholesterol and ApoB in girls and for the intake of 12:0 and ApoB in boys. These associations, as well as the positive relationships between for example the intake of eicosapentaenoic acid and docosahexaehoic acid and serum cholesterol and ApoB were retained, even after adjustment for different degrees of physical activity.

Relationships between intake of different foods and metabolic variables

The diets were divided into thirty-seven different food groups which were correlated with the metabolic variables. Very few significant associations could be demonstrated. Among the girls there were no significant associations at all

Table 4. Fatty acid composition (%) of the serum cholesterol esters*

(Mean values and standard deviations)

	All (*n* 93)		Girls (*n* 51)		Boys (*n* 42)		Statistical significance of difference between boys and girls: *P*
Fatty acid	Mean	SD	Mean	SD	Mean	SD	
12:0	0·16	0·06	0·15	0·07	0·17	0·06	0·036
14:0	0·99	0·19	0·97	0·20	1·01	0·19	0·380
15:0	0·26	0·06	0·25	0·06	0·27	0·07	0·108
16:0	11·18	0·68	11·01	0·66	11·41	0·66	0·004
16:1*n*-7	3·38	0·92	3·70	1·02	2·97	0·57	0·001
18:0	0·99	0·21	0·93	0·18	1·06	0·22	0·001
18:1*n*-9	21·12	1·70	21·03	1·81	21·24	1·57	0·560
18:2*n*-6	51·99	2·86	51·99	3·06	51·98	2·63	0·981
18:3*n*-6	0·82	0·33	0·89	0·38	0·75	0·22	0·168
18:3*n*-3	0·93	0·22	0·94	0·23	0·91	0·22	0·441
20:3*n*-6	0·73	0·12	0·72	0·12	0·73	0·11	0·747
20:4*n*-6	5·85	0·85	5·82	0·92	5·88	0·75	0·709
20:5*n*-3	0·95	0·34	0·94	0·32	0·97	0·37	0·620
22:6*n*-3	0·61	0·15	0·61	0·15	0·62	0·14	0·614

* For details of analytical procedures see p. 334.
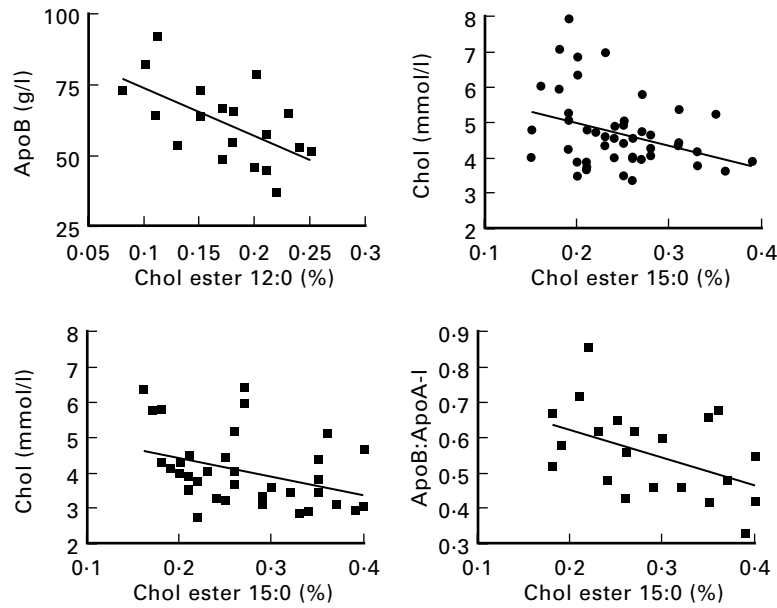
Fig. 1. Scatter plots showing the relationships between the proportions of certain saturated fatty acids in the serum cholesterol esters and the concentrations of cholesterol (Chol) and apolipoproteins (Apo) in serum. ■, boys, ●, girls. For details of analytical procedures see p. 334. Chol ester 12:0 $v.$ ApoB, boys r −0·61 $P <$ 0·01; Chol ester 15:0 $v.$ Chol, girls r −0·32, $P <$ 0·05; Chol ester 15:0 $v.$ Chol, boys r −0·34, $P <$ 0·05; Chol ester $v.$ ApoB:ApoA-I, boys r −0·50, $P <$ 0·05.

between the different food groups and ApoB, ApoA-I and insulin. There was a negative correlation between the serum cholesterol levels and the intake of juice (r −0·37, $P < 0·05$) and between the intake of vegetables and serum triacylglycerol (r −0·32, $P < 0·05$). Among the boys there were a few strong associations with an inverse association between the serum ApoB concentrations and the estimated intake of vegetables (r −0·63, $P < 0·01$) and a positive relationship with insulin. A similar pattern was seen for the intake of fruit and berries.

There were no significant relationships between the total amount of dairy products in the diet and the metabolic variables among the girls, while the intake of cheese was negatively associated with the serum cholesterol levels (r −0·35, $P < 0·05$) and the triacylglycerol (r −0·38, $P < 0·05$) among the boys. However, when the analysis was restricted to milk fat, as represented by the energy-adjusted intakes of the sum of 4:0–10:0 and 14:0 from dairy products, a pattern emerged which was very similar to that seen in Tables 5 and 6, with significant negative

Table 5. Relationships between serum cholesterol ester fatty acid composition (%) and metabolic variables in fifty-one girls and forty-two boys‡
(correlation coefficients)

Serum cholesterol ester fatty acid	Serum triacylglycerol		Serum cholesterol		Serum insulin		Serum ApoA-I‖		Serum ApoB¶		Serum ApoB:ApoA-I‖	
	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys
12:0			−0·34*	−0·53**			−0·39†	−0·48*		−0·61**		
14:0	+0·47***											
15:0			−0·32*	−0·34*			−0·55**			−0·43*		−0·50*
16:0												+0·43†
16:1n-7	+0·30*									+0·64**		+0·45*
18:0												
18:1n-9												
18:2n-6										−0·51*		−0·52*
18:3n-6	+0·42*			+0·60***						+0·49*		
18:3n-3												
20:3n-6				+0·36*		−0·44**				+0·63**		+0·73***
20:4n-6				+0·39*		−0·45**				+0·45*		
20:5n-3												
22:6n-3												

Apo, apolipoprotein.
* $P < 0·05$, ** $P < 0·01$, *** $P < 0·001$, † $P < 0·1$.
‡ For details of analytical procedures see p. 334. All data are adjusted by partial correlation for differences in BMI.
‖ Girls n 27, boys n 22.
¶ Girls n 28, boys n 22.

Table 6. Relationships between dietary fat intake (% energy) and metabolic variables in forty-two girls and fifty-one boys‡
(correlation coefficients)

Dietary fatty acids	Serum triacylglycerol		Serum cholesterol		Serum insulin		Serum ApoA-I||		Serum ApoB¶		Serum ApoB:ApoA-I||	
	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys
4:0–10:0		−0·36*	−0·32*			−0·43*			−0·42*	−0·40†		
12:0			−0·31*						−0·42*	−0·55**		−0·64**
14:0		−0·41*	−0·30*			−0·47**			−0·40*	−0·40†		
16:0		−0·50**				−0·42*						
16:1*n*-7	−0·32*											
18:0			−0·35*									−0·41†
18:1*n*-9												
18:2*n*-6												
18:3*n*-3												
20:4*n*-6	−0·42**			+0·38*								
20:5*n*-3	+0·29*		+0·33*	+0·48**				+0·57**	+0·49**	+0·46*	0·38†	
22:5*n*-3				+0·35*						+0·42†		
22:6*n*-3			+0·34*	+0·59***				+0·44*	+0·41*	+0·48*		

Apo, apolipoprotein.

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, † $P < 0.1$.

‡ Nutrient intake measured with a 7 d weighed food record and analysed using the Swedish National Food Administration (report no. 14, Pc version, 1992; Uppsala, Sweden). For details of analytical procedures see p. 334. All data are adjusted by partial correlation for differences in BMI.

\|\| Girls *n* 27, boys *n* 22.

¶ Girls *n* 28, boys *n* 22.

associations in both sexes to the ApoB levels and with similar tendencies for cholesterol (boys and girls) and insulin (girls).

The relationships between the intake of dietary fatty acids, and the fatty acid composition of the serum cholesterol esters respectively, and the clinical variables were reanalysed and adjusted for the intakes of vegetables and juice respectively, in girls as well as boys. The associations shown in Tables 5 and 6 remained virtually unchanged even after these adjustments.

Discussion

Dietary fat and serum lipids

The mean intake of saturated fat in different populations is directly related to the serum cholesterol concentrations and to the mortality in CHD (Keys *et al.* 1986). It has been suggested that a high intake of milk and butter fat may significantly contribute to this relationship (Artauld-Wild *et al.* 1993). In contrast, when studied within populations (Ascherio & Willett, 1995; Pietinen *et al.* 1997) it has not always been possible to demonstrate significant relationships between intake of saturated fat or fatty acids and the incidence of CHD. Similarly, it has been difficult to show significant correlations between dietary fat intake and serum lipid levels in observational studies within populations (Jacobs *et al.* 1979), in spite of the clear relationships between intake of saturated fatty acids and serum cholesterol and ApoB concentrations seen in a number of controlled intervention studies (Katan *et al.* 1995). There may be several reasons for this, e.g. insufficient precision of the methods for dietary surveys, large intraindividual day-to-day variations in food intake, genetic variants with high and low responders to the effects of dietary fat, or a small and heterogenous sample with regard to age and sex. Another possibility is that the relationships between dietary fat intake and serum lipid levels are more complex than has been realised hitherto.

Our subjects were recruited from, and well representative of, a carefully characterized population of adolescents, where the possible confounding effects of age and sex were eliminated. A well established, validated method for the dietary survey was used (weighed 7 d records). This may have facilitated the demonstration of several significant, and surprisingly strong, correlations between dietary fatty acids (Table 6, Fig. 2) and the serum cholesterol ester fatty acid composition (Table 5, Fig. 1) on the one hand and metabolic variables on the other. The dietary fat intake, as estimated from the dietary records, shows that a relatively low proportion of the energy is derived from fat (Table 2) with a rather low content of cholesterol. This is well in accordance with the dietary intake calculated for the whole group (Samuelson *et al.* 1996) and closely similar to that reported earlier from a study of 14- and 17-year-old boys and girls in northern Sweden (Bergström *et al.* 1995). The fatty acid patterns in the serum cholesterol esters (Table 3) were similar in boys and girls, as also shown earlier in Finnish children (Moilanen *et al.* 1986).

The dominating source of saturated fatty acids with chain lengths of four to ten, twelve and fourteen C atoms in the diet is milk fat (Gunstone *et al.* 1994). More than two-thirds of the short-chain fatty acids (four to ten C atoms) in the present study were derived from dairy fat among both boys and girls. This was also true for 50–60 % of the lauric (12:0) and myristic (14:0) acids while only approximately one-third of the palmitic (16:0) and palmitoleic (16:1) acids in the diet were derived from dairy fat. A larger proportion of the latter fatty acids, than of the saturated fatty acids with a shorter chain length, was derived from meat and meat products.

Serum fatty acid composition, fat intake and metabolic variables

Surprisingly, there were generally negative associations between the proportions of saturated fatty acids with chain
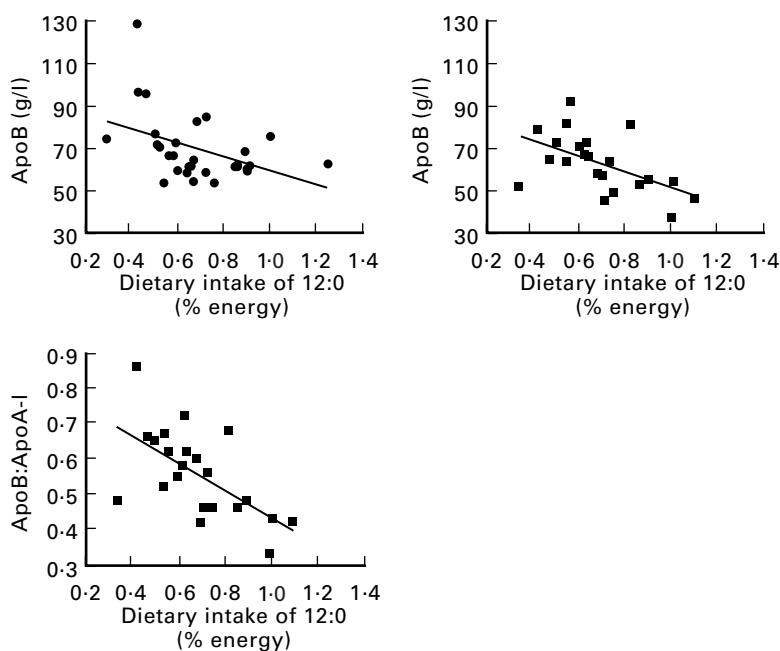
Fig. 2. Scatter plots showing the relationships between the proportion of lauric acid (12:0) in the diet and the concentrations of apolipoproteins (Apo) in serum. ■, Boys; ●, girls. For details of analytical procedures see p. 334. Nutrient intake was measured with a 7 d weighed record and analysed using the Swedish National Food Administration food database (report no. 14, Pc Version, 1992; Uppsala, Sweden). Dietary intake of 12:0 v. ApoB: girls r −0·42, $P < 0·05$; boys r −0·55 $P < 0·01$. Dietary intake of 12:0 v. ApoB:ApoA-I: boys r −0·64, $P < 0·01$.

lengths up to fifteen C atoms in the serum cholesterol esters (Table 5, Fig. 1) and in the diet (Table 6, Fig. 2), and the serum cholesterol and ApoB concentrations respectively. Few studies have earlier addressed this question. Moilanen *et al.* (1986) reported a positive, although rather weak, correlation between 14:0 in the serum cholesterol esters and the serum cholesterol and ApoB concentrations in Finnish children but did not analyse 12:0 or 15:0. In three large studies of the associations between dietary variables and plasma lipids and lipoproteins in the Lipid Research Clinics populations (Glueck *et al.* 1982; Gordon *et al.* 1982; Schwartz *et al.* 1982) very weak correlations were found between serum lipid levels and dietary fats, and no effort was made to separate the different saturated fatty acids in the diet. The relationships between the proportions of palmitoleic and linoleic acids in serum and ApoB (Table 5), and the positive relationships between the long-chain *n*-6 and *n*-3 fatty acids and the concentrations of serum cholesterol and serum ApoB (Table 5 and 6) are essentially in accordance with earlier findings (Moilanen, 1986).

The data presented here refer to correlations between the relative content of fatty acids in the diet and in the serum cholesterol esters and metabolic variables. Very similar results were seen when the absolute intake of fatty acids in the diet was used in the calculations, as well as when the analyses were done without adjustment for differences in BMI. In addition, adjustment for different degrees of physical activity did not change the main results.

The negative relationships between the content of saturated fatty acids with a chain length of less than sixteen C atoms in the diet and serum, and the serum ApoB

and cholesterol concentrations could be a chance finding. Although not possible to rule out, this does not seem very likely. The relationships were seen independently in girls as well as in boys. Similarly, rather strong correlations were seen in relation to both estimated intake of milk fat, to the intake of specific saturated fatty acids, and to the proportions of the corresponding fatty acids in serum.

It is well documented that the saturated fatty acids with twelve, fourteen and sixteen C atoms elevate the serum cholesterol concentrations when administered in the diet during controlled experiments (Katan *et al.* 1995). In accordance with this, positive relationships between the estimated intake of these fatty acids, or the proportions in serum, and the serum cholesterol and ApoB concentration would have been expected. The major source of saturated fatty acids in the diet with four to fourteen C atoms is milk fat. The proportions of 15:0 in serum cholesterol esters are directly associated with the estimated dairy fat intake (Smedman *et al.* 1999) and 15:0 in adipose tissue has been shown to be a surprisingly good marker for dietary intake of milk fat (Wolk *et al.* 1998).

It is conceivable that a high intake of dairy fat may be a part of a 'healthy food pattern' where other dietary factors counterbalance the expected associations between the saturated fat intake and lipid levels or that the correlations are due to some other characteristics of the food intake. To exclude the possibility that the relationships shown in Tables 5 and 6 were confounded by certain dietary patterns, we adjusted by ANOVA for the intake of certain food groups that in univariate analysis were significantly related to the variables studied, and repeated the analyses with

virtually unchanged results. The relationships between the total intake of dairy products and the metabolic variables were rather weak with the exception of a significant inverse relationship between intake of cheese and the serum cholesterol levels among the boys. However, when the fatty acids 4:0–10:0 and 14:0 in dairy products were chosen as markers for intake of milk fat, similar associations were seen as earlier supporting the idea that the relationships shown might (directly or indirectly) be associated with the intake of milk fat. Inverse relationships were also seen between the estimated intake of milk fat in elderly men and clinical variables such as BMI, waist circumference and LDL:HDL ratio (Smedman *et al.* 1999).

There is a possibility that dairy fat contains some component, in addition to the saturated fatty acids, which may have other effects on the serum lipoprotein pattern when supplied in the diet during long time periods. Thus, it has recently been suggested that conjugated linoleic acid, which is found in fat from ruminants, may have antiatherogenic and serum lipid lowering effects in rabbits (Lee *et al.* 1994) and in hamsters (Van Amelsvoort & Meijer, 1997).

It was earlier shown that a high intake of saturated fatty acids and a low intake of linoleic acid, or a low proportion of linoleic acid in the serum cholesterol esters, usually coincides with a relatively high proportion of the long-chain *n*-6 derivatives in serum, and also with long-chain unsaturated fatty acids of the *n*-3 series (Laserre *et al.* 1985). There is a competition between the *n*-6 and *n*-3 series for the desaturase and elongase enzymes (Siguel & Maclure, 1987). If the diet contains a high proportion of saturated fatty acids, and a low proportion of linoleic acid, the conversion of both linoleic acid and α-linolenic acid to long-chain unsaturated metabolites is increased. This may explain the positive relationships between serum cholesterol and ApoB on the one hand and the long-chain, unsaturated fatty acids on the other in this study. As linoleic acid comprises about 50 % total cholesterol ester fatty acids, an apparent reciprocal effect of linoleic acid and the long chain, unsaturated fatty acids on serum cholesterol, as judged from the proportions of fatty acids in serum, may also be due to some extent to passive redistribution of the less abundant fatty acids secondary to changes in linoleic acid proportions. This cannot, however, explain the associations between the dietary content of long-chain *n*-3 fatty acids and serum cholesterol and ApoB, which is more likely to be due to the well known LDL-elevating effect of *n*-3 fatty acids (Harris, 1997).

Acknowledgements

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