

# Nutritional Studies of Vegetarians

## IV. Dietary Fatty Acids and Serum Cholesterol Levels

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A NUTRITIONAL study of eighty-six lacto-ovo-vegetarians, twenty-six "pure" vegetarians and eighty-eight nonvegetarians, including a description of the diets with various nutrient calculations, was published earlier.<sup>1</sup> The serum cholesterol levels of these groups as related to fat intake<sup>2</sup> and the fiber in the diet<sup>3</sup> have also been reported.

This report presents the component fatty acids and the iodine values of fats consumed by these subjects, and their correlations with the serum cholesterol values. A table of fatty acids compiled by us<sup>4</sup> and a more recent one by the Department of Agriculture<sup>5</sup> were used as the basis for these calculations.

### RESULTS

The data obtained from the calculations of the dietaries of the respective groups are shown in Tables I, II and III. For convenient quantitative comparison the per cent intake of each fatty acid for the various groups is given.

Table IV, a modification of a table in an earlier publication,<sup>2</sup> summarizes the fat intakes and serum cholesterol levels of the respective groups. The cholesterol values were determined by the method of Bloor<sup>6</sup> which gives higher results than some others.<sup>7</sup>

Table V presents the correlation of the serum cholesterol with the dietary fat and the fatty

acid intakes of the adult groups. It does not include pregnant women or adolescents, since the cholesterol values within these respective groups do not differ significantly.

Table VI shows the ratios between the per cent of polyunsaturated:saturated fatty acids in the diets of all groups studied.

### COMMENTS

Table V shows that a highly significant inverse correlation exists between the level of serum cholesterol and the total unsaturated fatty acid intakes. This correlation appears to agree with the findings of several investigators that the serum cholesterol levels can be influenced by the quality of the fat ingested.<sup>8-11</sup>

As one might expect a similar significant inverse correlation is found between the degree of unsaturation of the dietary fats and the serum cholesterol. Ahrens and his associates<sup>10</sup> have indicated that the iodine value is the best measure of assessing the cholesterol elevating or depressing effect of a fat.

Another highly significant inverse correlation appears between the serum cholesterol and linoleic acid level in the diet in relation to the total fatty acid intake. It has been demonstrated<sup>12</sup> that plasma lipid levels can be lowered by the ingestion of large amounts of vegetable oils rich in linoleic acid and also by the addition to the diet of linoleic acid esters.<sup>13</sup>

It is of interest that the level of oleic acid intake is highest among pure vegetarians (males 55 per cent, females 52 per cent) and lowest among the nonvegetarians (males 45 per cent, females 45 per cent). The lacto-ovo-vegetarians, while holding an intermediate position (males 48 per cent, females 46 per cent) more closely approximated the intake of the nonvegetarians (Tables I, II and III).

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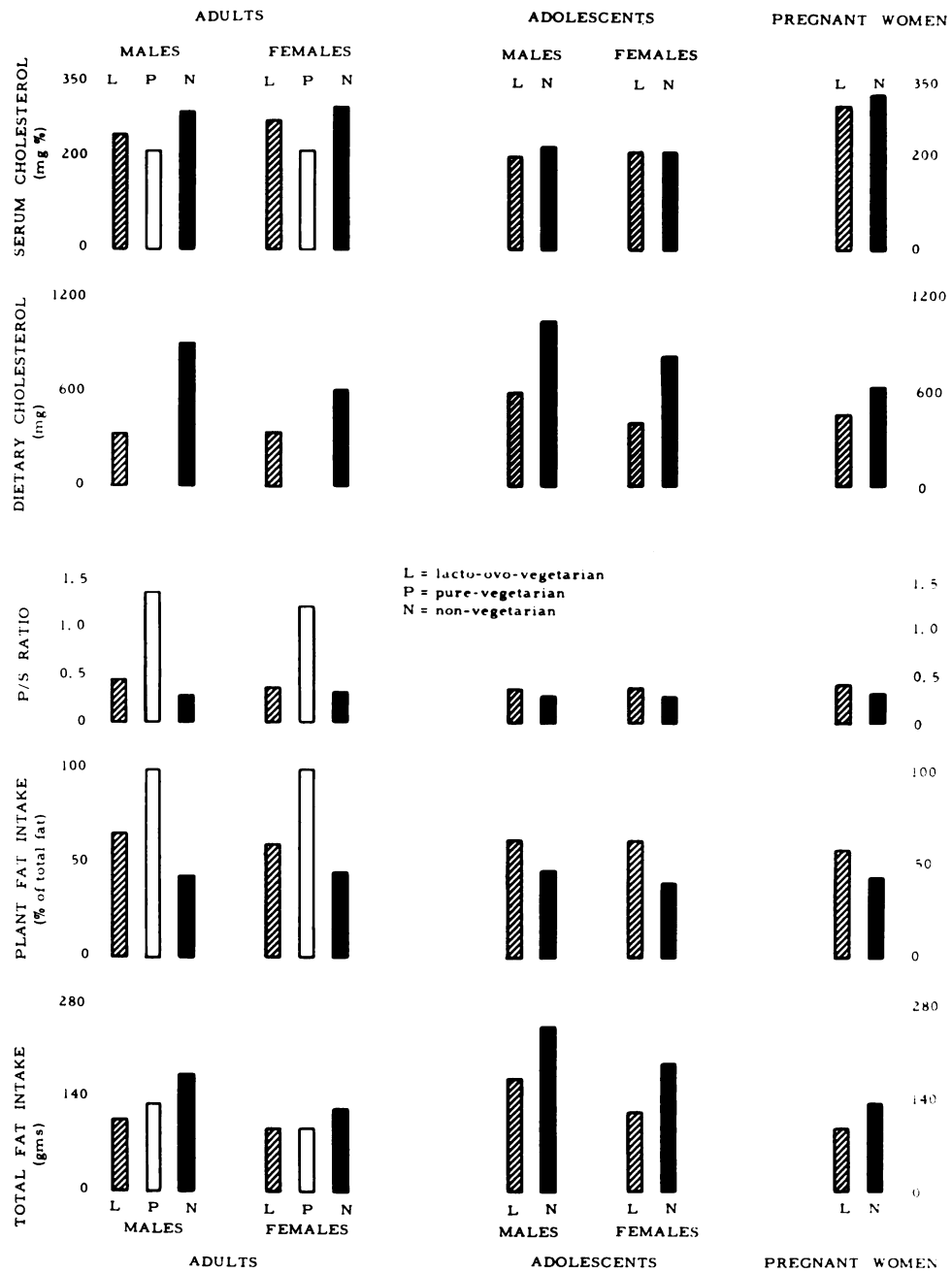


FIG. 1. The significant relationships between the amount of plant fat consumed, the ratio of polyunsaturated:saturated fatty acids (P:S ratio) and the intakes of dietary cholesterol to the serum cholesterol levels of all of the vegetarian and nonvegetarian groups is presented together with the total fat intake.

It has been suggested by Hegsted and associates that oleic and certain other unsaturated fatty acids may promote hypercholesteremia in the rat,<sup>14</sup> although they had little effect in the

chick.<sup>15</sup> Statistical analysis of the cholesterol level and the oleic acid intake of adults in all the dietary groups shows a significant negative correlation. Since the differences in serum



TABLE  
Fat and Fatty Acid Content

Fat, Fatty Acids and Iodine Number	Adults					
	Males			Females		
	Mean (gm.)	S. E.*	Per Cent †	Mean (gm.)	S. E.	Per Cent
Fat, total.....	171.7	12.32	...	121.2	15.69	...
Fatty acids.....	163.1	11.70	...	115.1	14.90	...
Saturated.....	67.4	4.78	41.3	46.8	6.78	40.7
Unsaturated.....	95.7	7.45	58.7	68.3	8.38	59.3
Tetradecenoic (C <sub>14</sub> )....	0.7	0.06	0.4	0.5	0.06	0.4
Hexadecenoic (C <sub>16</sub> )....	4.6	0.33	2.8	3.3	0.33	2.9
Oleic (C <sub>18</sub> ).....	73.3	5.76	44.9	52.2	6.86	45.3
Linoleic (C <sub>18</sub> ).....	16.3	1.49	10.0	11.2	1.14	9.7
Linolenic (C <sub>18</sub> ).....	0.7	0.08	0.4	0.5	0.07	0.4
Arachidonic (C <sub>20</sub> )....	1.3	0.10	0.8	1.0	0.09	0.9
C <sub>22</sub> .....	0.4	0.05	0.2	0.3	0.04	0.3
Iodine number.....	103.2	9.24	60.1	70.4	8.84	58.1

\* Standard error.

cholesterol concentrations among the respective groups is more marked than the differences in the oleic intake, it would appear that some other factor may have influenced the blood cholesterol levels. Keys<sup>16</sup> suggests that the level of oleic acid in the diet plays a neutral role in this respect.

Of the small amount of arachidonic acid, as well as of the still more highly unsaturated fatty acids present in food fats, the nonvegetarians ingested the most, the lacto-ovo-vegetarians less and the pure vegetarians none. Since the serum cholesterol levels of those who consumed the most of these highly unsaturated acids were

TABLE  
Fat and Fatty Acid Content of

Fat, Fatty Acids and Iodine Number	Adults					
	Males			Females		
	Mean (gm.)	S. E.*	Per Cent †	Mean (gm.)	S. E.	Per Cent
Fat, total.....	104.0	7.87	...	88.7	5.70	...
Fatty acids.....	98.8	7.46	...	84.3	6.35	...
Saturated.....	33.4	2.55	33.8	32.3	3.10	38.3
Unsaturated.....	65.4	5.62	66.2	52.0	4.05	61.7
Tetradecenoic (C <sub>14</sub> )....	0.3	0.04	0.3	0.4	0.05	0.4
Hexadecenoic (C <sub>16</sub> )....	1.4	0.14	1.4	1.5	0.18	1.8
Oleic (C <sub>18</sub> ).....	47.9	3.90	48.5	38.7	2.97	45.9
Linoleic (C <sub>18</sub> ).....	14.8	1.75	15.0	10.5	1.26	12.4
Linolenic (C <sub>18</sub> ).....	0.4	0.04	0.4	0.2	0.02	0.3
Arachidonic (C <sub>20</sub> )....	0.4	0.07	0.4	0.4	0.05	0.5
Iodine number.....	74.3	6.75	71.5	54.5	4.26	61.4

\* Standard error.

I  
of Diets of Nonvegetarians

Adolescents						Pregnant Women		
Males			Females					
Mean (gm.)	S. E.	Per Cent	Mean (gm.)	S. E.	Per Cent	Mean (gm.)	S. E.	Per Cent
243.3	16.94	...	187.9	14.48	...	129.8	6.41	...
231.1	16.09	...	178.5	13.75	...	123.3	6.08	...
95.4	6.18	41.3	75.4	5.40	42.2	48.8	2.80	39.6
135.7	10.40	58.7	103.1	8.08	57.8	74.5	3.67	60.4
1.0	0.10	0.4	0.8	0.08	0.5	0.8	0.04	0.6
5.9	0.36	2.5	5.2	0.43	2.9	3.3	0.17	2.7
102.4	7.47	44.3	77.3	5.85	43.3	55.9	6.89	45.3
25.0	2.63	10.8	18.5	1.98	10.4	13.0	0.74	10.5
0.8	0.08	0.3	0.6	0.05	0.3	0.4	0.02	0.3
1.5	0.11	0.7	1.5	0.16	0.8	1.6	0.08	1.3
0.4	0.04	0.2	0.5	0.10	0.3	0.3	0.03	0.2
147.2	11.74	60.5	110.3	8.79	58.7	79.2	3.66	61.0

† Per cent of total fatty acids.

higher than the levels of those who consumed less, or none, the question arises as to whether any possible cholesterol depressing effect of these types of unsaturated fatty acids was counteracted by the comparatively large intake of saturated acids by these subjects. Kinsell et al.<sup>13</sup> have reported a fall in serum cholesterol

in a patient after the administration of 75 gm. daily of a phosphatide mixture containing 12.5 per cent tetraoic acid (probably arachidonic). Other investigators<sup>9,10,17,18</sup> present evidence that the higher polyunsaturated fatty acids, or those of marine oils, depress cholesterol levels in man. However, Keys et al.<sup>19</sup> fed a concen-

II  
Diets of Lacto-Ovo-Vegetarians

Adolescents						Pregnant Women		
Males			Females					
Mean (gm.)	S. E.	Per Cent	Mean (gm.)	S. E.	Per Cent	Mean (gm.)	S. E.	Per Cent
164.7	9.13	...	114.6	7.61	...	93.6	5.62	...
156.5	8.67	...	108.9	7.22	...	88.6	5.31	...
56.4	3.53	36.0	39.3	2.50	36.1	32.9	2.10	37.1
100.1	5.86	64.0	69.6	5.60	63.9	55.7	3.41	62.9
0.6	0.05	0.4	0.4	0.04	0.4	0.4	0.03	0.4
2.5	0.17	1.6	1.8	0.14	1.6	1.6	0.10	1.8
76.2	4.44	48.7	52.5	4.33	48.2	39.9	2.43	45.0
19.0	1.83	12.1	13.6	1.37	12.4	12.6	0.98	14.1
0.4	0.04	0.3	0.3	0.04	0.3	0.3	0.02	0.4
0.7	0.06	0.4	0.5	0.04	0.4	0.4	0.03	0.5
107.8	5.29	65.5	76.7	6.57	66.9	63.0	3.91	67.3

† Per cent of total fatty acids.

TABLE III  
Fat and Fatty Acid Content of Pure Vegetarian Diets

Fat, Fatty Acids and Iodine Number	Adults					
	Males			Females		
	Mean (gm.)	S.E.*	Per Cent †	Mean (gm.)	S.E.	Per Cent
Fat, total . . . . .	120.5	16.96	...	92.5	15.07	...
Fatty acids . . . . .	114.4	16.11	...	87.9	16.48	...
Saturated . . . . .	21.3	5.41	18.6	19.0	4.15	21.6
Unsaturated . . . . .	93.1	11.67	81.4	68.9	14.04	78.4
Tetradecenoic (C <sub>14</sub> ) . . . . .	...	...	...	...	...	...
Hexadecenoic (C <sub>16</sub> ) . . . . .	...	...	...	...	...	...
Oleic (C <sub>18</sub> ) . . . . .	63.4	9.26	55.4	45.3	8.66	51.6
Linoleic (C <sub>18</sub> ) . . . . .	28.3	3.68	24.7	22.2	5.82	25.3
Linolenic (C <sub>18</sub> ) . . . . .	1.0	0.08	0.9	0.8	0.16	0.9
Arachidonic (C <sub>20</sub> ) . . . . .	...	...	...	...	...	...
C <sub>22</sub> . . . . .	...	...	...	...	...	...
Iodine number . . . . .	115.9	14.55	96.2	85.8	19.55	92.6

\* Standard error.

† Per cent of total fatty acids.

trate of arachidonic acid to six men and found that a daily intake of 4 to 5 gm. of the acid not only failed to lower blood cholesterol but also actually raised it.

Of the positive correlations summarized in Table v, the total intake of animal fat and the corresponding serum cholesterol values are the most significant ( $P = 0.01$ ). Several investigators<sup>20-23</sup> working with human subjects found that fats of animal origin apparently increase blood cholesterol concentrations. Toor et al.<sup>24</sup> report that recent immigrants to Israel of Yemenite Jews, whose diet is largely vegetarian, have significantly lower blood cholesterol levels than earlier Yemenite immigrants who have adopted the Israel diet. Our present findings are in keeping with our previously published report<sup>2</sup> and that of others<sup>25,26</sup> that a dietary regimen with a generous intake of plant fats may be associated with low serum cholesterol. The mean intake of fat of the adult nonvegetarians significantly exceeds that of the respective vegetarian groups. The lacto-ovo-vegetarians show the lowest total fat intake and derived a larger proportion of their fat from plant foods than did the nonvegetarians.

Figure 1 graphically depicts the significant

relationships between the intakes of plant fat, the polyunsaturated:saturated fatty acid ratio, the dietary cholesterol and the levels of serum cholesterol of the respective groups studied. As already pointed out in a previous report,<sup>2</sup> the total fat intake may not significantly affect the level of blood cholesterol. In this study the degree of unsaturation and the level of plant fats consumed are inversely associated with cholesterol levels. This relationship is striking when the ratio of polyunsaturated:saturated fatty acids is considered. Available data fail to clearly define whether the cholesterol depressing effects are due to the degree of unsaturation of the fat or to the type of unsaturated fat. Ahrens<sup>10</sup> has proposed that the serum cholesterol level is a function of the net unsaturation of the dietary fats as measured by their iodine number. Jolliffe<sup>27</sup> suggests that it may be a function of their polyunsaturated:saturated ratio. It has been observed<sup>28</sup> that sardine oil, although highly unsaturated, is less cholesterol depressing and coconut oil less cholesterol elevating than would be expected if the degree of unsaturation were the major factor.

Some of the pure vegetarians consumed up to 25 per cent of their fat calories in the form

TABLE IV  
Dietary Fat Intake and Serum Cholesterol Levels of Vegetarian and Nonvegetarian Groups

Groups	No. of Subjects	Fat Intake (gm.)	S.E.	Per Cent of Calories from Fat	Cholesterol (mg./100 ml.*)
<i>Adults</i>					
<i>Males</i>					
Lacto-ovo-vegetarians.....	15	107.6	7.86	33.1	243
"Pure" vegetarians.....	14	130.2	18.37	35.2	206
Nonvegetarians.....	15	175.5	11.05	43.0	288
<i>Females</i>					
Lacto-ovo-vegetarians.....	15	92.2	7.49	33.3	269
"Pure" vegetarians.....	11	96.9	18.20	34.2	206
Nonvegetarians.....	15	124.2	15.83	41.7	295
<i>Adolescents</i>					
<i>Males</i>					
Lacto-ovo-vegetarians.....	15	167.4	8.95	34.0	194
"Pure" vegetarians.....	0	...	...	...	...
Nonvegetarians.....	15	246.6	16.85	41.3	214
<i>Females</i>					
Lacto-ovo-vegetarians.....	15	118.9	7.86	34.5	206
"Pure" vegetarians.....	0	...	...	...	...
Nonvegetarians.....	15	192.6	14.35	41.8	209
<i>Pregnant women</i>					
Lacto-ovo-vegetarians.....	26	96.1	5.58	32.6	303
"Pure" vegetarians.....	0	...	...	...	...
Nonvegetarians.....	28	132.0	6.20	39.5	325

\* Bloor's method. Results approximately 7.5 per cent higher than results by Schoenheimer and Sperry's method.<sup>7</sup>

of coconut oil or coconut butter. The cholesterol levels of these subjects, although in certain cases somewhat higher than the mean for the group, were still significantly lower than those of the groups using large amounts of animal fats. Their respective cholesterol levels showed no consistent pattern with the types of plant fats used. From the degree of saturation of coconut fat (92 per cent), one might have expected higher cholesterol levels among those who used it freely. Reports of the effect of natural and hydrogenated coconut fat on the blood cholesterol concentration in man vary.<sup>9,11,29,30</sup> The common use of this oil in the dietary of the Philippine armed forces failed to produce high serum cholesterol levels.<sup>31</sup>

From the statistics of twenty countries Jolliffe and Archer<sup>32</sup> found high correlation between the consumption of saturated fats and the death rate from degenerative heart disease. Bronte-Stewart<sup>33</sup> showed a significant relationship between the ratio of polyunsaturated: saturated fatty acids in the diets, and the mortality figures for atherosclerotic heart disease

TABLE V  
Correlation of Serum Cholesterol with Dietary Fat and Fatty Acid Intake Adult Vegetarian and Non-vegetarian Groups

Fat and Fatty Acids	R*	p
<i>All Groups</i>		
Unsaturated†.....	-0.514	<0.001
Oleic.....	-0.251	<0.05
Linoleic.....	-0.499	<0.001
Linolenic.....	-0.281	<0.02
<i>Lacto-Ovo-Vegetarians and Nonvegetarians</i>		
Animal fat.....	+0.374	<0.01
Arachidonic acid.....	+0.066	>0.1
Tetradecenoic (C <sub>14</sub> ).....	+0.049	>0.1
Hexadecenoic (C <sub>16</sub> ).....	+0.247	<0.05
<i>Nonvegetarians only</i>		
Unsaturated C <sub>22</sub> .....	-0.211	>0.1

\* R = Coefficient of correlation.

† Iodine number. r = -0.520; p = 0.001.

TABLE  
Ratio of Polyunsaturated:Saturated Fatty Acids in the

Groups	Lacto-Ovo-Vegetarians				Pure	
	Fatty Acids				No.	Polyunsaturated Fatty Acids (% total)
	No.	Polyunsaturated Fatty Acids (% total)	Saturated Fatty Acids (% total)	P:S* Ratio		
<i>Adults</i>						
Males.....	15	15.8	34.8	0.45	14	25.6
Females.....	15	13.2	38.3	0.36	11	23.0
<i>Adolescents</i>						
Males.....	15	12.8	36.0	0.36		
Females.....	15	13.1	36.1	0.36		
<i>Pregnant women</i> .....	26	15.0	37.1	0.40		

\* Polyunsaturated:saturated fatty acid ratio.

in various countries. Keys<sup>34</sup> had earlier correlated the relationship of dietary fat with the serum cholesterol and the mortality from ischemic heart disease.

Table VI shows the ratio of the total polyunsaturated:saturated fatty acids. A comparison of the respective adult male and female groups shows that the pure vegetarians have a polyunsaturated:saturated fatty acid ratio approximately five and four times that of the nonvegetarians and three and a half times that of the lacto-ovo-vegetarians. The levels of serum cholesterol in these groups are directly related to these ratios. It would thus appear that the type of fat consumed is more important than the total fat intake and that as the polyunsaturated:saturated fatty acid ratio increases, the level of serum cholesterol decreases.

As observed in Tables I, II and III the general character of the fat and the fatty acid content of the adolescents and pregnant women in the groups of vegetarians and nonvegetarians are similar to those of the adults in the respective groups. In these older age groups, as had already been noted, a generous intake of animal fat correlated with a significantly higher serum cholesterol level than was found in those using mostly plant fats. This was not the finding in the younger age groups. The serum cholesterol levels of adolescents and pregnant women

did not differ significantly for vegetarians and nonvegetarians in their respective groups. From this finding it would appear, as was postulated earlier,<sup>2</sup> that some physiologic mechanism is present in young persons which is able to equate dietary differences and maintain lower blood cholesterol levels than result in older persons on similar diets. With advancing age this mechanism apparently fails.

Beveridge found<sup>35</sup> that in normal young adults dietary cholesterol can significantly raise plasma cholesterol levels, but that the response appears to plateau above an intake of 200 mg. per 950 calories, or approximately 600 mg. per day, which he considers to be the intake of most people on a nonvegetarian diet. The non-vegetarians in this study consumed from 600 to 1,000 mg. cholesterol per day. In another study<sup>36</sup> of the effects of different dietary fats on the serum cholesterol concentration of young men and women, the lowest serum values were obtained with corn oil and the highest with butter. The authors concluded that the results depended on the initial serum cholesterol values and on the cholesterol content of the diet.

It appears possible that as the compensatory mechanism fails the dietary cholesterol may play an increasingly significant role in elevating serum cholesterol levels. As reported earlier<sup>2</sup> a direct and highly significant relationship



vi

Diets of Vegetarian and Nonvegetarian Groups

Vegetarians		Nonvegetarians			
Saturated Fatty Acids (% total)	P:S* Ratio	Fatty Acids			
		No.	Polyunsaturated Fatty Acids (% total)	Saturated Fatty Acids (% total)	P:S Ratio
18.6	1.38	15	11.4	41.3	0.28
19.0	1.21	15	12.7	40.7	0.31
		15	12.0	41.3	0.29
		15	11.8	42.2	0.28
		28	12.3	39.6	0.31

exists between the dietary intakes of cholesterol and the level in the serum of the various groups studied. Recently Connor and his associates,<sup>37</sup> working with six middle-aged male subjects, demonstrated a significant rise in serum cholesterol on the addition of egg yolk cholesterol to the diet and a marked decline when it was withdrawn. Crystalline cholesterol added in similar amounts gave lower serum cholesterol levels than egg yolk cholesterol. It is suggested that the serum cholesterol response may be influenced by the nature of the fat with which the added cholesterol is associated.

#### SUMMARY AND CONCLUSION

The fat, fatty acid intake and serum cholesterol levels of groups of adult lacto-ovo-vegetarians, pure vegetarians and nonvegetarians have been analyzed and compared. The findings indicate that (1) significant negative correlations exist between the serum cholesterol level in the older age groups and the total unsaturated fatty acids, the iodine value of the fat, the linoleic and oleic acid contents of the diet; (2) significant positive correlations exist between the per cent of animal fat, hexadecenoic fatty acids and serum cholesterol levels in the older age groups; (3) a highly significant inverse relationship exists between the ratio of polyunsaturated:saturated fatty acids and serum cholesterol in the older age

groups; and (4) in the younger age groups studied (adolescents and pregnant women), despite differences in fat and fatty acid intakes in their respective groups, the serum cholesterol levels did not differ significantly between the vegetarians and nonvegetarians.

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