NUTRITIONAL STUDIES OF VEGETARIANS*

2. DIETARY AND SERUM LEVELS OF CHOLESTEROL

MERVYN G. HARDINGE, M.D.† AND FREDRICK J. STARE, M.D.

In the United States the vegetarian groups afford a singular opportunity to compare dietary intakes and serum cholesterol concentrations with those of control groups. Eighty-six lacto-ovo-vegetarian, twenty-six "pure" vegetarian, and eighty-eight non-vegetarian adults, adolescents, and pregnant women were studied. Lacto-ovo-vegetarians include milk and eggs in their diet but do not eat flesh of animals (meat, poultry, fish). "Pure" vegetarians eat no foods of animal origin. Details regarding the selection and composition of these groups, together with a report on their dietary practices, physical condition, and laboratory findings are described in the preceding paper. This study discusses the cholesterol findings.

METHODS

Tables for the estimation of cholesterol in the diets were prepared from data reported by Okey[1] and reproduced in part by Turner,[2] while dietary fat was calculated from the food composition tables of the United States Department of Agriculture[3] and Bowes and Church.[4] Serum cholesterol was determined by the method of Bloor.[5]

RESULTS

The caloric consumption and levels of fat and cholesterol in the diets of the various groups have been summarized in Table I. The average calories derived from total dietary fat approximate the estimate of 38 per cent for the United States made by the Food and Agriculture Organization.[6] In Table II, the per cent of calories obtained from total fat, together with that fraction furnished by animal fat alone, are compared between corresponding groups. The non-vegetarians have significantly higher intakes in both instances.

The dietary cholesterol of the non-vegetarians is definitely greater than that of the lacto-ovo-vegetarians. The "pure" vegetarians, because of exclusion of all foods of animal origin, have essentially cholesterol-free diets. The serum cholesterol levels of these groups are compared in Table III. No significant differences exist between the lacto-ovo-vegetarian and non-vegetarian groups, with the exception of the adult lacto-ovo-vegetarian males, who have a significantly lower value. When the lower serum cholesterol concentrations of the "pure" vegetarian groups are compared with their respective lacto-ovo-vegetarian and non-vegetarian groups, a high degree of significance is observed. The cholesterol levels of the expectant mothers are not excessive, as there is customarily a rise in blood cholesterol concentration during pregnancy.

DISCUSSION

At the outset, it should be mentioned that the number of subjects in this study is small.

From the Department of Nutrition, Harvard School of Public Health, Boston.

* The data presented in this paper represent partial fulfillment (by M.G.H.) of the requirements for the degree of Doctor of Public Health at the Harvard School of Public Health.

† School of Medicine, College of Medical Evangelists, Loma Linda, California.

Supported in part by a grant-in-aid from the Nutrition Foundation, New York.

TABLE I

Caloric, Fat, and Cholesterol Intake of Vegetarians and Non-vegetarians

Group	No.	Total calories	Total fat	Calories from fat	Cholesterol	
					Total	Mg./100 calories
			Gm.	%	*mg.*	
ADULTS						
Males						
L-o-vegetarian*	15	3020	107.6	33.1	333	11.0
"Pure" vegetarian	14	3260	130.2	35.2	0	
Non-vegetarian	15	3720	175.5	43.0	914	24.6
Females						
L-o-vegetarian	15	2450	92.2	33.3	350	14.3
"Pure" vegetarian	11	2400	96.9	34.2	0	
Non-vegetarian	15	2690	124.2	41.7	612	22.8
ADOLESCENT						
Males						
L-o-vegetarian	15	4450	167.4	34.0	599	13.5
Non-vegetarian	15	5350	246.6	41.3	1046	19.5
Females						
L-o-vegetarian	15	3030	118.9	34.5	408	13.5
Non-vegetarian	15	4100	192.6	41.8	829	20.2
PREGNANT WOMEN						
L-o-vegetarian	26	2650	96.1	32.6	464	17.5
Non-vegetarian	28	3010	132.0	39.5	627	20.8

* Lacto-ovo-vegetarian. See text.

Because of that, the results reported can only be considered as possibly suggesting interesting trends.

The daily intake of exogenous cholesterol by the lacto-ovo-vegetarians and non-vegetarians is suprisingly different. This difference is explained by considering the sources of cholesterol in the diets. The use of eggs by both groups is approximately the same. Although the lacto-ovo-vegetarians do consume more milk than the non-vegetarians, yet to the cholesterol obtained by the non-vegetarians from dairy products must be added the significant amount contained in various meats, fish, and fowl. As recently pointed out by Phil,[7] a liter of milk contains approximately 135 milligrams of cholesterol, a quantity which may be smaller than that contributed by the average serving of meat eaten at dinner (100–150 mg.).

The cholesterol-free diet of the "pure" vegetarian is of special interest because of the use in the past decade of low cholesterol diets for individuals with atherosclerosis. The observations[8] that dietary fat, whether of animal or vegetable origin, may influence the blood cholesterol level and the investigations of several workers [9–11] using diets low in both cholesterol and fat have indicated that serum cholesterol levels may reflect the fat rather than the cholesterol intake. In this study, there exists a direct quantitative correlation between blood cholesterol concentrations and the level of animal rather than total fat in the diet. Thus the "pure" vegetarians, despite the free use of plant fats, but on diets devoid of animal fat, have the lowest serum cholesterol values. This is in accord with the recent observations of Kinsell and associates, [12,13] who found that subjects on diets containing large amounts of vegetable fat showed a marked decrease in serum cholesterol.

It has been pointed out by Moses[14] that "neither moderate increases or decreases in dietary cholesterol exert any consistently significant effect upon blood cholesterol levels." However, the duration of the dietary program may be a factor of importance. In most studies relating cholesterol content of diets and levels of serum cholesterol, subjects have pursued the experimental regimes for relatively short periods of time. In this investigation,

TABLE II

Comparison of Fat Intakes of Vegetarian and Non-vegetarian Groups

	L-o-vegetarian Group I			"Pure" vegetarian Group II			Non-vegetarian Group III			Comparison of groups: I & III		II & III		I & II	
	No.	Mean	S.D.	No.	Mean	S.D.	No.	Mean	S.D.	Diff. of Means	S.E. of Diff.	Diff. of Means	S.E. of Diff.	Diff. of Means	S.E. of Diff.
Per cent of Calories from Total Fat															
ADULT															
Males	15	33.1	7.11	14	35.2	10.07	15	43.0	5.35	9.9	2.30	7.8	3.40	2.1	3.40
Females	15	33.3	5.94	11	34.2	10.06	15	41.7	4.35	8.4	1.89	7.5	3.38	0.9	3.54
ADOLESCENT															
Males	15	34.0	4.31	1	51.3	—	15	41.3	2.51	7.3	1.77	—	—	—	—
Females	15	34.5	5.11	—	—	—	15	41.8	5.09	7.3	2.02	—	—	—	—
PREGNANT WOMEN	26	32.6	6.57	—	—	—	28	39.5	5.53	6.9	1.66	—	—	—	—
Per cent of Calories from Animal Fat															
ADULT															
Males	15	9.4	4.54	—	—	—	15	25.1	7.13	15.7	2.18	—	—	—	—
Females	15	13.1	5.53	—	—	—	15	23.9	6.69	10.8	2.24	—	—	—	—
ADOLESCENT															
Males	15	12.7	3.57	—	—	—	15	22.4	5.26	9.7	1.61	—	—	—	—
Females	15	13.2	4.22	—	—	—	15	25.2	6.07	12.0	1.91	—	—	—	—
PREGNANT WOMEN	26	13.8	4.98	—	—	—	28	26.0	6.27	12.2	1.54	—	—	—	—

TABLE III

Comparison of Serum Cholesterol Levels of Vegetarian and Non-vegetarian Groups

Groups	L-o-vegetarian			"Pure" vegetarian			Non-vegetarian			Comparison of groups							
										I & III			II & III			I & II	
	No.	Group I Cholesterol Mean	S.D.	No.	Group II Cholesterol Mean	S.D.	No.	Group III Cholesterol Mean	S.D.	Diff. of Means	S.E. of Diff.		Diff. of Means	S.E. of Diff.		Diff. of Means	S.E. of Diff.
		mg./100 ml.			*mg./100 ml.*			*mg./100 ml.*									
ADULT																	
Males	15	243	21.2	14	206	35.0	15	288	49.0	45	13.8		82	15.7		37	10.8
Females	15	269	61.0	11	206	32.7	15	295	62.8	26	22.6		89	19.0		63	18.6
ADOLESCENT																	
Males	15	194	26.7	—	—	—	15	214	35.0	20	11.6		—	—		—	—
Females	15	206	41.3	—	—	—	15	209	32.2	3	13.5		—	—		—	—
PREGNANT WOMEN	26	303	53.9	—	—	—	28	325	65.9	22	16.3		—	—		—	—

the lacto-ovo-vegetarians had maintained their dietary regimes of moderate cholesterol content throughout life, while the "pure" vegetarians had all consistently followed their cholesterol-free diets for a minimum of five or more years. Is it possible that the continued ingestion of exogenous cholesterol carried in animal fats over many years contributes to the gradual increase in serum cholesterol?

Because of the rarity of "pure" vegetarian subjects and the paucity of reliable clinical criteria, it was not possible to determine the incidence of atherosclerosis among the groups studied. Whether significant or not, it is interesting that no hypertensive subjects were observed among the "pure" vegetarians, although cases were encountered with equal frequency among the lacto-ovo-vegetarians and non-vegetarians.[15] The possible endogenous synthesis of cholesterol[16] from overgenerous caloric intake should be considered. The significantly lower body weight of the "pure" vegetarian men and women (average twenty pounds) as compared to the lacto-ovo-vegetarian and non-vegetarian adult groups may indicate, as suggested in an earlier paper,[15] that the efficiency of caloric utilization may be less in those subsisting on an all plant dietary than of those using foods of both animal and plant origin.

The possibility of a relationship between body weight and cholesterol level was examined. The subjects of each group were divided into those above or below their mean group weight, and those above or below their desirable weights. No correlation between weight and cholesterol concentration was found.

Keys *et al.*[17] have observed a relationship between serum cholesterol levels and age, where a gradual rise occurs in both sexes after the age of 30. Others[18,19] have reported similar findings. In Table IV, the subjects have been grouped according to age, being divided into those above or below mean group age. In general, the older subjects have measurably but not significantly higher cholesterol values. However, if the cholesterol levels of the lacto-ovo-vegetarian and non-vegetarian adoles-

TABLE IV
Comparison of Age and Cholesterol Values of Vegetarian and Non-vegetarian Groups

Groups	Subjects less than mean age			Subjects more than mean age			Comparison of groups	
	No.	Mean	S.D.	No.	Mean	S.D.	Diff. of Means	S.E. of Diff.
ADULTS								
Lacto-vegetarian								
Males	7	238.9	24.95	8	246.5	20.0	7.6	11.8
Females	5	260.8	85.13	10	273.6	56.17	12.8	32.0
"Pure" vegetarian								
Males	7	190.4	19.5	7	222.6	31.2	32.2	15.0
Females	5	192.6	7.18	5	217.2	31.8	24.6	16.6
Non-vegetarian								
Males	9	275.9	53.21	6	313.2	48.07	37.3	26.5
Females	8	254.8	28.78	7	341.4	59.83	86.6	24.8

cents (Table III) are compared with the values for their respective adult groups, a significant increase in concentrations is seen.

Since the intake of dietary cholesterol of all groups of non-vegetarians was significantly greater than that of the corresponding lacto-ovo-vegetarian groups, it is possible that in the younger age groups (adolescents) of both sexes, where serum cholesterol levels are similar, the body has the ability to control or eliminate the excesses of both the endogenous or exogenous cholesterol, and thus maintain the serum cholesterol at a lower level. In the adult groups, however, the difference between the serum cholesterol concentrations of lacto-ovo-vegetarians and non-vegetarians is gradually widening. This might suggest that with advancing age the body's capacity to eliminate excess cholesterol, whether from endogenous or exogenous origin, diminishes, and that a gradual accumulation of cholesterol results.

Summary

The cholesterol intakes, as determined by calculation, and serum cholesterol measurements of a limited number of "pure" vegetarian, lacto-ovo-vegetarian, and non-vegetarian pregnant women, adolescents, and adults of both sexes are reported. The dietary cholesterol is higher in the non-vegetarian groups than in the lacto-ovo-vegetarian groups. The "pure" vegetarians' diet is, of course, cholesterol-free.

Serum cholesterol levels of the adult vegetarian groups tend to be lower than the adult non-vegetarian groups, the pure vegetarians having the lowest values. The significantly lower serum cholesterol concentration of the "pure" vegetarians occurred despite a free intake of vegetable fat. Cholesterol levels appear more closely correlated to the intake of animal fat than of total fat.

The higher serum cholesterol concentrations of the older adult groups as compared with the younger groups would support the observation of others that there occurs a gradual increase in cholesterol levels with advancing age. Since the differences in serum cholesterol in the adolescent age groups is only slight, it is suggested that with aging there may occur a diminishing ability of the body to handle excess cholesterol, whether of endogenous or exogenous origin.

Acknowledgment

The senior author wishes to express his appreciation to Mrs. Bertha S. Burke, Dr. Robert B. Reed, and Dr. George V. Mann for their help and advice during the course of this study.

References

1. Okey, R.: Cholesterol content of foods. *J. Am. Dietet. A.* 21: 341, 1945.
2. Turner, D.: *Handbook of Diet Therapy.* University of Chicago Press, Chicago, Illinois, 1946.
3. Watt, B. K., and Merrill, A. L.: Composition of foods—raw, processed, prepared. *Agriculture Handbook*, No. 5, U. S. Department of Agriculture, 1950.
4. Bowes, A. D., and Church, C. F.: *Food Values of Portions Commonly Used.* Published by Senior Author, Philadelphia, 1951.

5. Bloor, W. R.: The determination of cholesterol. *J. Biol. Chem.* 24: 227, 1916.
6. Food and Agriculture Organization: *Food Balance Sheets.* Washington, D. C., 1949.
7. Phil, A.: Cholesterol studies. I The cholesterol content of food. *Scand. J. Clin. Lab. Invest.* 4: 115, 1952.
8. Keys, A., Chapman, L. B., Mickelsen, O., and Miller, E. v. O.: The relation in man between cholesterol levels in the diet and in the blood. *Science* 112: 79, 1950.
9. Mellinkoff, S. M., Machella, T. E., and Reinhold, J. G.: The effect of a fat-free diet in causing low serum cholesterol. *Am. J. Med. Sc.* 220: 203, 1950.
10. Morrison, L. M., Zwirlein, M., and Wolfson, E.: The effects of low fat—low cholesterol diets on the serum lipids. *Circulation* 2: 475, 1950.
11. Hildreth, E. A., Mellinkoff, S. M., Blair, G. W., and Hildreth, D. M.: The effect of vegetable fat ingestion on human serum cholesterol concentration. *Circulation* 3: 641, 1951.
12. Kinsell, L. W., Partridge, J., Boling, L., Sheldon, M., and Michaels, G.: Dietary modification of serum cholesterol and phospholipid levels. *J. Clin. Endocr. & Metab.* 12: 909, 1952.
13. Kinsell, L. W., Michaels, G. D., Partridge, J. W., Boling, L. A., Balch, H. E., and Cochrane, G. C.: Effect upon serum cholesterol and phospholipids of diets containing large amounts of vegetable fat. J. Clin. Nutrition 1: 224, 1953.
14. Moses, C.: Dietary cholesterol and atherosclerosis. *Am. J. Med. Sc.* 224: 212. 1952.
15. Hardinge, M. G., and Stare, F. J.: Nutritional studies of vegetarians. 1. Nutritional, physical, and laboratory studies. J. Clin. Nutrition 2: 73, 1954.
16. Block, K., and Rittenberg, D.: On the utilization of acetic acid for cholesterol formation. *J. Biol. Chem.* 145: 625, 1942.
17. Keys, A., Mickelsen, O., Miller, E. O., Hayes, E. R., and Todd, R. L.: The concentration of cholesterol in the blood serum of normal man and its relation to age. *J. Clin. Investigation* 29: 1347, 1950.
18. Sperry W. M., and Webb, M.: The effect of increasing age on serum cholesterol concentration. *J. Biol. Chem.* 187: 107, 1950.
19. Gertler, M. M., Garn, S. M., and Bland, E. F.: Age, serum cholesterol and coronary artery disease. *Circulation* 2: 517, 1950.

Resumen

Estudios nutricionales de vegetarianos. 2. Dieta y niveles de colesterol del suero

Se reporta la ingesta de colesterol determinada por medio de cálculos y medidas de colesterol del suero en un número limitado de mujeres encintas, adolescentes y adultos de ambos sexos, vegetarianos "puros," lacto-ovo-vegetarianos y no vegetarianos. El colesterol de la dieta es mayor en los grupos no vegetarianos que en los lacto-ovo-vegetarianos. La dieta de los vegetarianos "puros" es, por supuesto, libre del colesterol.

Los niveles de colesterol del suero tienden a ser menores en el grupo de adultos vegetarianos, encontrándose los valores menores en los vegetarianos "puros." Los niveles significativamente menores del colesterol del suero del grupo de vegetarianos "puros" ocurrieron a pesar de la ingesta libre de grasa vegetal. Los niveles de colesterol aparecen más directamente relacionados con la ingesta de grasa animal que con la de grasa total.

Las concentraciones más altas de colesterol del suero en el grupo de adultos mayores en comparación con el grupo de jóvenes puede soportar la observación realizada por otros autores de que ocurre un aumento gradual de los niveles de colesterol conforme avanza la edad. Desde que las diferencias en el colesterol del suero en los grupos de adolescentes es solamente ligera, se sugiere que con la edad puede ocurrir una disminución de la habilidad del organismo para "manejar" el exceso de colesterol, ya sea de origen endógeno o exógeno.

Correction

In Vol. 1 (7), page 534, column 2, line 3, for 0.1, read 0.001.