Clinical Reports

Nutritional Status of Adolescent Children

IV. Cholesterol Relationships*

MARGARET MCGREGOR HARD, M.S.† AND NETTIE C. ESSELBAUGH, PH.D.‡

CHOLESTEROL metabolism and the fate of food cholesterol in the human organism are of considerable interest to nutritional and medical personnel. Okey[1] has stated that those factors likely to be involved in cholesterol metabolism are the amount of dietary cholesterol; the amount and composition of the fat, phospholipids and protein in the diet; the amount and type of dietary lipotropic agents and the status of the person as to hormone secretion and vitamin intake.

As part of a study of the nutritional status of adolescent children[2–4] information was obtained on cholesterol and vitamin intake, serum cholesterol level, intake of animal and vegetable fat and protein, basal metabolic rate, weight, hemoglobin, hematocrit and blood pressure. Relationships between cholesterol and these factors in a normal adolescent group consuming an average American diet were examined and are reported herein.

PROCEDURE

The subjects for the study were 248 fifteen and sixteen year old boys and girls who had been born and reared in either Snohomish or Yakima County of Washington. Approximately equal numbers of boys and girls made up each age group in each area.

Dietary Data

The amounts of intake of cholesterol, fat, protein and vitamins were obtained from semiquantitative seven-day dietary records.[2] Vitamin supplements were recorded separately. Cholesterol content of the diets was calculated from values supplied by Okey[5,6] supplemented by information from Dobbin, Gofman, Jones, Lyon and Young.[7] The other nutrients were calculated from values in the U.S. Department of Agriculture, Agriculture Handbook Number 8,[8] Bowes and Church,[9] Bradley,[10] and Boyd, Eads and Sandstead.[11]

Serum Cholesterol

Free and total cholesterol determinations were made on fasting blood. Serum was stored in the frozen state until it could be analyzed by the method of Schoenheimer and Sperry.[12]

Physical Measurements

Basal metabolic rates were determined in duplicate with the Sanborn metabolator. The subjects slept at the laboratory the night previous to the determination. Weight and blood pressure were taken as part of an extensive physical examination performed by a research physician. Hemoglobin was determined by Wintrobe's alkaline hematin colorimetric method,[13] and hematocrit by the Wintrobe and Handsberg method.[13]

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† Professor of Food and Nutrition, Washington State University, Pullman, Washington.
‡ Present address: Sumner, Washington.

TABLE I
Mean Daily Intake of Cholesterol, Calories, Protein and Fat by Area and Sex

Nutrient	Snohomish County		Yakima County	
	Boys (63)	Girls (62)	Boys (61)	Girls (61)
Cholesterol (mg.)	837.0 ± 35.0*	579.0 ± 23.0*	782.0 ± 30.0*	575.0 ± 24 0*
Calories	3,181.0 ± 90.13	2,213.0 ± 67.13	3,119 0 ± 67 65	2,048.0 ± 57.86
Protein				
Total (gm.)	108.9 ± 3.22	75.9 ± 2.54	101.2 ± 2.60	71.8 ± 2.76
Per cent of calories	14.0	14.0	13.0	14.0
Animal (gm.)	71.1	51.4	63.7	48.5
Vegetable (gm.)	37.9	24.5	37.5	23.4
Fat				
Total (gm.)	146.2 ± 5.53	100.2 ± 3.82	141.3 ± 4.68	91.9 ± 3.40
Per cent of calories	41.0	40.0	40.0	40.0
Animal (gm.)	94.8	63.8	84.4	56.2
Vegetable (gm.)	51.4	36.5	56.9	35.7

* Standard error of the mean.

Statistical Treatment of Data

Daily mean intake of cholesterol, animal and vegetable protein and fat, total fat, total protein and calories were obtained for boys and girls in Snohomish and Yakima counties. Free and total serum cholesterol, body weight, hemoglobin, hematocrit, systolic and diastolic blood pressures, and basal metabolic rates also were expressed as mean values for these groups of subjects.

Analysis of variance was used for comparison between groups.[14]

Correlations were calculated for the four groups. Cholesterol intake was correlated with serum cholesterol level, weight, and basal metabolic rate. Serum cholesterol was correlated with fat, protein, calorie and vitamin intake, basal metabolic rate, weight, hemoglobin, hematocrit and blood pressure.[14]

RESULTS AND DISCUSSION

Cholesterol Intake

Analyses of variance revealed a significant difference ($P < 0.01$) between the cholesterol intake of the boys and girls (Table I). There were no significant differences ($P > 0.05$) between areas or between the fifteen and sixteen year old subjects. The intake of subjects from Washington was similar to that of the adolescents from Idaho.[15] Subjects from both Washington and Idaho consumed somewhat larger amounts of cholesterol than the thirteen to fifteen year old subjects in Colorado, Montana, or Utah[15] (Table II).

On the whole, the cholesterol intake of the teen-age groups is similar to values reported for younger and older age groups (Table II).

Relation to Weight and Basal Metabolic Rates: Cholesterol intake was not significantly ($P > 0.05$) correlated with weight or with basal metabolic rate. This was true for both boys and girls. Separation of the subjects into those that were 20 per cent or more overweight or underweight did not change the correlation.

Serum Cholesterol Levels

Significant differences ($P < 0.01$) in total serum cholesterol were found between areas and between sexes. The subjects from Yakima (boys and girls combined) had higher values than those from Snohomish. The serum levels were consistently higher in girls (both areas combined) than in boys (Table III). About 25 per cent of the total cholesterol was in the free form in all groups. These values are similar to serum cholesterol values reported for subjects in Idaho[16] (Table III). They are, however, higher than values given for teen-agers from Montana[17] and for thirteen to nineteen year old subjects from Utah.[18]

TABLE II
Comparison of Cholesterol Intakes and Serum Cholesterol Levels for Subjects of Varying Ages

Location	Age (yr.)	Cholesterol Intake (mg./day)			Total Serum Cholesterol Levels (mg./100 ml.)		
		Reference	Male	Female	Reference	Male	Female
New York	2 mo. to 3 yr.	..	..	..	20	171.4	179.2
	4, 5 and 6	..	..	..	..	175.7	179.9
	7, 8 and 9	..	..	..	..	185.8	192.7
Utah	5 to 9	15	544	496	18	159.0	175.0
New York	10 to 12	..	..	..	20	189.1	180.9
Utah	10 to 12	15	629	588	18	176.0	176.0
Utah	13 to 19	15	744	519	18	154.0	162.0
Colorado	13 to 15	15	593	418	..	...	...
Montana	13 to 15	15	783	471	17	133.0	144.0
Idaho	13 to 15	15	804	523	16	166.3	175.3
Washington	15 to 16	..	810	577	..	165.3	177.6
Utah	25 to 49	15	932	545	..	...	...
California	50 to 54	15	772	480	19	252.0	267.0
Colorado	50 to 54	15	644	379	..	...	...
California	80+	15	624	349	19	216.0	236.0
Colorado	80+	15	534	349	..	...	...

The difference between areas is difficult to explain. Dietary intake of cholesterol, protein, fat and calories (Table I) tends to be lower in Yakima than in Snohomish county although the differences are not significant ($P > 0.05$). Two other factors may have a bearing, e.g., the difference in the amount of sunshine in Snohomish and Yakima counties, and the difference in the physical build of the boys in the two areas. The Yakima area, on the average, has approximately twice as much sunshine as the Snohomish area.[2] The reconversion of 7-dehydrocholesterol formed by the action of the sun on skin cholesterol might account for some of the increased cholesterol in the serum of the subjects from Yakima. Kritchensky[19] points out that 7-dehydrocholesterol can be converted to cholesterol. Another contributing factor may be body build. Kornerup[20] reports that slender men have lower serum cholesterol levels than heavy men. Twenty-eight of the Snohomish boys (44 per cent) and fourteen of the Everett boys (23 per cent) could be classified as "slender." The average serum cholesterol value of the slender Snohomish boys was 150 mg./100 ml. but 179 mg./100 ml. for the slender Yakima boys. The additional number of slender boys in the Snohomish group may account for some of the area difference in serum cholesterol levels.

Differences in serum cholesterol levels between the sexes have been found in adolescents in Montana[17] and Idaho[16] and in elderly subjects in California.[21] There appears to be a tendency for the serum level of prepuberty girls to be somewhat higher than the level of the boys (Table II) although the difference is of doubtful significance. During adolescence, the level appears to drop, particularly in the boys. A variation in hormonal control is suggested although this may not be the only factor involved. Aftergood, Deuel and Alfin-Slater[23] have postulated that the increased cholesterol plasma level in female rats is due to the smaller requirement of the female rat for essential fatty acids. This, in turn, releases more of the ingested essential fatty acids for transport of cholesterol. Although the human requirement for essential fatty acids is not well established, this hypothesis may partially explain the sex differences observed in human serum cholesterol levels.

Effect of Dietary Constituents: A significant correlation did not exist between cholesterol intake and total serum cholesterol (r = −

TABLE III
Mean Serum Cholesterol Values by Area and Sex

Total Serum Cholesterol Levels	Snohomish County		Yakima County	
	Boys (63)	Girls (61)	Boys (62)	Girls (61)
Mean (mg./100 ml.)	156.7	173.7	173.9	181.4
Range (mg./100 ml.)	98.8–232.6	115.1–297.9	111.0–244.7	123.0–235.1
Standard error	4.17	4.81	4.13	3.62
Free (% of total)	24.6	25.5	26.2	26.4

0.1853 for the girls; r = + 0.1813 for the boys). Cholesterol intake and free serum cholesterol did correlate significantly for the subjects from Snohomish (r = − 0.5187 for the girls; r = + 0.2697 for the boys). The negative correlation for the girls and the positive correlation for the boys emphasizes the sex-linked difference: the cholesterol intake of the girls was lower than that of the boys but the serum level was higher (Table II). An association between free serum cholesterol and cholesterol intake was found also in teen-age subjects from Montana.[17] A positive correlation between total serum cholesterol and daily cholesterol intake of aging subjects was reported from California and Wyoming.[21,24]

Significant correlations ($P<0.05$) with calories and with protein intake occurred only with the boys from Snohomish: calories correlated positively ($P < 0.05$) with free and total serum cholesterol; protein correlated ($P < 0.01$) with free and total. The proportion of animal to vegetable protein was similar for all groups, ranging from 62.9 per cent to 67.8 per cent animal protein and from 32.2 per cent to 37.1 per cent plant protein. No significant relation ($P > 0.05$) was found between the serum cholesterol level and fat intake. The proportion of animal to vegetable fat ranged from 59.7 per cent to 64.9 per cent animal fat and from 35.1 per cent to 40.3 per cent plant fat (Table I). An examination of Tables I and III indicates a lack of positive association between the serum cholesterol level and the intake of protein, fat and calories. The girls from Yakima with the highest level of total serum cholesterol consumed the smallest amounts of fat, protein and calories. Conversely, the boys from Snohomish with the highest consumption of cholesterol, calories, protein and fat, had the lowest level of total serum cholesterol. Guild and Odland[17] confirm these findings in teen-agers. In aging Californian subjects[21] protein and fat intakes did relate significantly to serum cholesterol values. Swanson et al.,[25] studying midwestern women ranging in age from twenty to ninety years, reported that dietary protein and fat explained a negligible amount of the variation in serum cholesterol.

The intakes of some of the vitamins correlated positively with serum cholesterol levels in the boys from Snohomish: thiamine with free and total ($P < 0.05$), riboflavin with free and total ($P < 0.01$); niacin with free and total ($P < 0.05$); vitamin A with free and total ($P < 0.05$); and ascorbic acid with free and total ($P < 0.01$).

Positive relationships were also noted in the boys from Snohomish between calcium intake and total serum cholesterol ($P < 0.05$), calcium and free ($P < 0.01$), phosphorus intake with free and total ($P < 0.01$), and iron intake with free and total serum cholesterol ($P < 0.01$). It is difficult to explain the vitamin and mineral correlations. They may have occurred merely through chance. There is always the possibility, however, of a metabolic relationship as yet not identified. For instance, serum ascorbic acid as well as ascorbic acid intake correlated ($P < 0.05$) with free and total serum cholesterol. Also a significant positive correlation ($P < 0.01$) was found for all subjects between serum carotene and free and total serum cholesterol. A possible relationship between ascorbic acid and cholesterol

TABLE IV
Mean Values for Selected Physical Measurements

Physical Measurement	Snohomish County				Yakima County			
	No.	Boys	No.	Girls	No.	Boys	No.	Girls
Body weight (lb.)	63	135.0 ± 2.84*	62	117.0 ± 2.05*	61	135.0 ± 3.67*	61	121.0 ± 2.12*
Basal metabolism (cal./sq. M./hr.)	62	38.9 ± 0.488	60	34.0 ± 0.498	61	39.8 ± 0.427	61	33.8 ± 0.408
Hemoglobin (gm./100 ml.)	63	14.6 ± 0.098	62	13.6 ± 0.093	61	15.0 ± 0.143	62	13.3 ± 0.149
Hematocrit (%)	63	48.5 ± 0.331	62	45.2 ± 0.294	61	47.2 ± 0.321	62	43.8 ± 0.263
Blood pressure	63		60		61		61	
Systolic (mm. Hg)	..	115.0 ± 1.27	..	109.0 ± 1.16	..	115.0 ± 1.37	..	108.0 ± 1.04
Diastolic (mm. Hg)	..	70.0 ± 1.06	..	67.0 ± 0.91	..	70.0 ± 1.00	..	69.0 ± 0.86

* Standard error of the mean.

and between carotene and cholesterol is suggested. Ascorbic acid and cholesterol metabolism is currently under further investigation in this laboratory.

Relation to Body Weight: Mean body weights for the four groups of subjects are given in Table IV. A simple correlation between weight and serum cholesterol revealed no relationship between these two factors for the groups as a whole. Likewise, there was no evident relationship between body weight and total serum cholesterol in subjects who were 20 per cent or more overweight or underweight. This contrasts with findings in Montana[17] where free and total serum cholesterol levels were positively associated with weight deviation in fifteen year old boys. In aging subjects in California[21] extreme under- or overweight was found to be associated with low and high serum cholesterol levels in men but not in women. Also, Payne[24] found no relation between weight and serum cholesterol in aging women. Swanson et al.[25] reported no significant relationship between weight and serum cholesterol in women from twenty to ninety years of age.

Relation to Basal Metabolic Rate: The mean basal metabolic rates for each of the four groups of subjects are presented in Table IV. These values are within the range given for adolescents.[26] Serum cholesterol and basal rates have been closely associated in hypothyroidism.[27] However, in these subjects a positive significant correlation ($P < 0.05$) was found only with the boys from Snohomish ($r = +0.3143$). This finding is similar to results found in healthy subjects in the midwestern states.[21,25]

Relation to Blood Pressure: No relation was found between blood pressure and total serum cholesterol. Systolic and diastolic pressures (Table IV) were within the normal range for fifteen and sixteen year old boys and girls[26,29] Gillum et al. and Swanson et al.[21,25] also found no relationship between blood pressure and serum cholesterol levels in men and women.

Relation to Hemoglobin and Hematocrit: Payne[24] has recently reported a significant correlation between hemoglobin and total serum cholesterol in women over sixty years of age living at an altitude of 7,200 feet. This relationship, she postulates, may be due to the high altitude and to hematopoietic changes occurring with age. Similar correlations for the adolescent age group have not been reported to date.[16,17,30] In the adolescent subjects in Washington, hemoglobin and hematocrit positively correlated ($P < 0.05$) with free and total serum cholesterol in the girls from Snohomish. Hemoglobin and hematocrit values of these subjects (Table IV) are similar to those reported for adolescent girls from Idaho, Montana and Utah.[16,17,30]

SUMMARY AND CONCLUSIONS

Relationships between the serum cholesterol content and food intake (cholesterol, protein.

fat, vitamins, calories), body weight, basal metabolic rate, blood pressure, hemoglobin and hematocrit of 248 adolescent boys and girls are examined.

The aforementioned factors which have been reported to influence cholesterol metabolism in some other groups appear to have little if any relationship to serum cholesterol content in healthy fifteen and sixteen year old subjects consuming a normal American diet. The effect of sex on total serum cholesterol level is definite. This suggests that hormone secretion is one of the main factors regulating cholesterol metabolism during the adolescent period.

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