Plasma lipids and lipoproteins and the prevalence of risk for coronary heart disease in Canadian adults

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Objective: To report population reference values for blood lipids, to determine the prevalence of lipid risk factors and to assess their association with other risk factors.
Design: Population-based cross-sectional surveys. Survey participants were interviewed at home and provided a blood sample at a clinic. All blood lipid analyses were done in the Lipid Research Laboratory, University of Toronto. The laboratory is standardized in the National Heart, Lung Blood Institute-Centres for Disease Control Standardization Program.
Setting: Nine Canadian provinces, from 1986 to 1990.
Participants: A probability sample of 26 293 men and women aged 18 to 74 was selected from the health insurance registers for each province. Blood samples were obtained from 16 924 participants who had fasted 8 hours or more.
Outcome measures: Concentration of total plasma cholesterol, triglycerides and high density lipoprotein (HDL) and low density lipoprotein (LDL) cholesterol in blood samples from fasting participants.
Main results: Of the study population, 46% had total plasma cholesterol levels above 5.2 mmol/L, 15% had LDL-cholesterol levels above 4.1 mmol/L, 15% had triglyceride levels above 2.3 mmol/L and 8% had HDL-cholesterol levels below 0.9 mmol/L. Total plasma cholesterol, LDL-cholesterol and triglyceride levels rose with age in men to a maximum in the 45–54 age group; in women there was little change with age up to ages 45 to 54, at which time the level of each of these lipids increased appreciably. The age-standardized prevalence of obesity was positively associated with elevation of total plasma cholesterol.
Conclusion: The results suggest the need for a multifactorial approach in health promotion efforts to lower blood cholesterol levels and reduce other risk factors in the population. A considerable number of adults were found to be at risk at all ages in both sexes. In the short term, men aged 34 and older and women aged 45 and older might benefit most from prevention programs.

Elevated blood cholesterol and other dyslipoproteinemias are the major risk factors for coronary heart disease (CHD) and other ischemic vascular disease complications.[1-4] The influence of elevated blood cholesterol as a risk factor for CHD is enhanced by smoking and high blood pressure.[5,6]

Significant reduction of ischemic heart disease is obtainable with relatively modest lowering of blood cholesterol level of most adult Canadians.[7-10] Reducing other risk factors can further decrease CHD.[11,12]

This paper reports reference values for plasma lipids, the prevalence of the major lipid and lipoprotein CHD risk factors and their relation to other risk factors determined in statistically designed probability samples of the population in nine provincial heart health surveys carried out between 1986 and 1990.

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Methods

Levels of total plasma cholesterol, triglycerides and high density lipoprotein (HDL) cholesterol were measured in blood samples from participants who were asked to fast for 12 hours before giving samples. Data reported here are for subjects who fasted at least 8 hours. Mean lipid levels for people fasting 8 hours or more were no different from those for people fasting 12 hours or more (data not shown). In the field, blood samples were drawn into vacutainer tubes containing solid Na_2EDTA. Blood was kept cold and was centrifuged within 3 hours of collection. In the few cases where refrigerated centrifuges were not available, blood was centrifuged within 1 hour of collection. Plasma was transferred to tubes for shipment to the laboratory. All samples were shipped with ice packs and most were received by the laboratory within 24 hours of collection. Although difficulties in shipping were experienced at a few remote sites, those samples were received by the laboratory within 48 hours.

All blood lipid analyses were done at the Lipid Research Laboratory, University of Toronto, which is certified under the National Heart, Lung and Blood Institute–Centers for Disease Control Lipid Standardization Program.[13]

The analyses of samples from Nova Scotia, New Brunswick, Prince Edward Island and Newfoundland were performed using the Technicon Autoanalyzer II (Technicon–Miles, Mississauga, Ont.) and the chemical methods of the Lipid Research Clinics Project for determination of cholesterol and triglycerides.[13] The samples from British Columbia, Alberta, Saskatchewan, Manitoba and Quebec were analysed using the Technicon RA1000 and Technicon enzymatic reagents for determination of cholesterol (Technicon method SM4-0139G86), triglycerides (Technicon method SM4-0173G90) and triglyceride blank reagent (no. T01-2013-01) (Technicon–Miles, Mississauga, Ont.).

HDL-cholesterol was measured as the cholesterol in the supernatant after precipitation of the non-HDL-cholesterol using heparin and 46 mM $MnCl_2$. When enzymatic methods were used, Mn^{2+} was first removed using $NaHCO_3$.[14]

Low density lipoprotein (LDL) cholesterol was calculated from the plasma cholesterol, triglycerides and HDL-cholesterol concentrations expressed in mmol/L using the Friedewald formula:[15]

LDL-cholesterol = plasma cholesterol − (HDL-cholesterol + (triglyceride/2.2))

LDL-cholesterol level was not calculated when triglyceride concentration was greater than 4.52 mmol/L. The triglyceride value was corrected for blank values when triglyceride concentration was greater than 3.39 mmol/L.

All samples were analysed when internal quality control met the criteria for acceptable performance of the Lipid Research Clinics Project[13] and the external quality control met the requirements for standardization.[13] The average between-run coefficients of variation as determined from results of Part III of the standardization program were cholesterol 1.3%, triglyceride 3.96%, HDL-cholesterol 3.5%. The bias of the cholesterol measurements as determined from Part III pools and analysis of split-fresh specimens by the US National Cholesterol Reference Network was −1.6%.

The cutoff points in the plasma lipid and lipoprotein distributions used to assign risk of CHD were derived from the Canadian Consensus Conference on Cholesterol,[1] the National Cholesterol Education Program[2] and the European Atherosclerosis Society[3] without modification for age and sex. The desirable level for total plasma cholesterol was defined as less than 5.2 mmol/L, moderate risk as 5.2 to 6.2 mmol/L and high risk as greater than 6.2 mmol/L. For triglyceride the desirable level was defined as less than 2.3 mmol/L and risk level as 2.3 mmol/L or greater. For LDL-cholesterol the desirable level was defined as less than 3.4 mmol/L, moderate risk as 3.4 to 4.1 mmol/L and high risk as greater than 4.1 mmol/L. For HDL-cholesterol the desirable level was defined as greater than 0.9 mmol/L and at risk as 0.9 mmol/L or less.

The methods followed in the provincial heart health surveys, including sample design, training, quality control and data processing and analysis are described in the survey methods paper in this supplement.

Results

Response rates

Of those invited to participate, 64% provided a fasting sample (see paper on survey methods and data analysis, Table 1, page 1972). The lowest participation rate was for men 18 to 34 (60%) and the highest for women 35 to 64 (70%).

Reference values

For men, mean total cholesterol increased from 4.35 mmol/L for the 18–24 age group to 5.69 for the 45–54 age group (Table 1). After age 54, the mean total cholesterol levels decreased slightly. More than 25% of the 45–54 age group had a total cholesterol level greater than 6.2 mmol/L. For women, mean total cholesterol increased gradually from 4.49 mmol/L at ages 18 to 24 to 6.06 mmol/L at ages 65

to 74. Total cholesterol levels were higher in men than in women between the ages of 25 and 54, after which values in women were higher.

For men, mean triglyceride level increased from 1.27 mmol/L for the 18–24 age group to 2.07 mmol/L for the 45–54 age group (Table 2). In the following two decades mean triglyceride value declined. More that 25% of the 45–54 age group had a triglyceride level greater than the risk cut-off point of 2.3 mmol/L.

For women, mean plasma triglyceride level did not change much between ages 18 and 44 years. Thereafter, it increased rapidly with age to 1.87 mmol/L for the 65–74 age group. Triglyceride levels for women in this group approached the peak values for men aged 45 to 54. Triglyceride levels were appreciably higher in men than in women up to age 64; after this levels were higher in women. Mean triglyceride values exceeded the median consistently, in keeping with a log normal distribution.

The overall trends for LDL-cholesterol paralleled those for total plasma cholesterol (Table 3). For men, LDL-cholesterol increased rapidly from 2.55 mmol/L for ages 18 to 24 to 3.62 mmol/L for ages 45

Table 1: Means, standard deviations and selected percentiles for total plasma cholesterol level (mmol/L) in fasting subjects by sex and age

Sex; age, yr	No. of subjects	Mean (and SD*)	Percentile		
			25th	50th	75th
Men					
18–24	1 243	4.35 (0.84)	3.80	4.25	4.79
25–34	2 816	4.88 (0.96)	4.21	4.78	5.49
35–44	1 195	5.43 (0.94)	4.76	5.38	6.07
45–54	783	5.69 (1.05)	4.93	5.59	6.38
55–64	780	5.56 (1.01)	4.84	5.53	6.20
65–74	1 531	5.53 (1.03)	4.82	5.51	6.19
All	8 348	5.19 (1.06)	4.44	5.12	5.87
Women					
18–24	1 333	4.49 (0.84)	3.94	4.40	4.94
25–34	2 980	4.68 (0.90)	4.08	4.59	5.13
35–44	1 231	4.89 (0.88)	4.27	4.84	5.34
45–54	868	5.45 (0.96)	4.82	5.39	5.99
55–64	765	5.95 (0.97)	5.32	5.88	6.60
65–74	1 394	6.06 (1.10)	5.38	5.97	6.75
All	8 571	5.13 (1.09)	4.35	5.01	5.78
Total	16 919	5.16 (1.07)	4.40	5.06	5.82

*SD = standard deviation.

Table 2: Means, standard deviations and selected percentiles for plasma triglyceride levels (mmol/L) in fasting subjects by sex and age

Sex; age, yr	No. of subjects	Mean (SD)	Percentile		
			25th	50th	75th
Men					
18–24	1 243	1.27 (0.77)	0.76	1.07	1.50
25–34	2 816	1.49 (1.28)	0.89	1.23	1.76
35–44	1 195	1.96 (1.76)	1.09	1.52	2.22
45–54	783	2.07 (1.47)	1.17	1.78	2.63
55–64	780	1.84 (1.17)	1.04	1.54	2.34
65–74	1 531	1.74 (0.92)	1.08	1.55	2.14
All	8 348	1.71 (1.37)	0.98	1.39	2.06
Women					
18–24	1 333	1.19 (0.56)	0.80	1.08	1.43
25–34	2 980	1.13 (0.61)	0.74	0.98	1.33
35–44	1 231	1.23 (0.73)	0.79	1.01	1.41
45–54	868	1.50 (0.82)	0.94	1.31	1.79
55–64	765	1.76 (0.92)	1.13	1.52	2.20
65–74	1 393	1.87 (1.42)	1.24	1.67	2.13
All	8 570	1.38 (0.87)	0.85	1.16	1.67
Total	16 918	1.54 (1.16)	0.90	1.26	1.87

to 54, after which it dropped slightly. For women, mean LDL-cholesterol values increased gradually from 2.58 mmol/L for ages 18 to 24 to 2.92 mmol/L for ages 35 to 44, then more rapidly to 3.83 mmol/L for ages 65 to 74. This rapid increase in LDL-cholesterol among women was some 20 years later than that for men. Mean LDL values for men exceeded those for women between ages 25 and 54, but after age 54, mean values for women exceeded those of men. More than 25% of men over 24 years and women over 44 years exceeded the risk level of 3.4 mmol/L for LDL-cholesterol.

The values for HDL-cholesterol showed no significant trend with age (Table 4). Women had higher values than men at all ages; the mean HDL-cholesterol level for women was about 0.22 mmol/L higher than that of men.

Prevalence of lipid risk factors

The prevalence of total plasma cholesterol above the desirable level of 5.2 mmol/L was 48% in men and 43% in women (Table 5). For 18% of men and 16% of women, total plasma cholesterol level

Table 3: Means, standard deviations and selected percentiles for low density lipoprotein (LDL) cholesterol level (mmol/L) in fasting subjects by sex and age

Sex; age, yr	No. of subjects	Mean (SD)	Percentile		
			25th	50th	75th
Men					
18–24	1 225	2.55 (0.71)	2.08	2.49	2.94
25–34	2 752	3.00 (0.84)	2.40	2.91	3.52
35–44	1 145	3.39 (0.83)	2.82	3.30	3.89
45–54	744	3.62 (0.89)	3.00	3.52	4.18
55–64	757	3.47 (0.86)	2.90	3.41	4.00
65–74	1 493	3.53 (0.93)	2.91	3.51	4.10
All	8 116	3.22 (0.91)	2.59	3.14	3.78
Women					
18–24	1 325	2.58 (0.71)	2.10	2.46	2.98
25–34	2 958	2.75 (0.79)	2.23	2.67	3.16
35–44	1 214	2.92 (0.79)	2.36	2.88	3.37
45–54	854	3.28 (0.80)	2.73	3.29	3.79
55–64	751	3.70 (0.88)	3.10	3.64	4.32
65–74	1 364	3.83 (1.01)	3.15	3.80	4.52
All	8 466	3.08 (0.92)	2.40	2.99	3.65
Total	16 582	3.15 (0.92)	2.50	3.07	3.72

Table 4: Means, standard deviations and selected percentiles for high density lipoprotein (HDL) cholesterol level (mmol/L) by sex and age

Sex; age, yr	No. of subjects	Mean (SD)	Percentile		
			25th	50th	75th
Men					
18–24	1 234	1.22 (0.27)	1.03	1.20	1.37
25–34	2 798	1.20 (0.29)	1.01	1.18	1.37
35–44	1 187	1.18 (0.31)	0.96	1.13	1.34
45–54	776	1.15 (0.27)	0.96	1.10	1.29
55–64	775	1.22 (0.34)	0.96	1.15	1.42
65–74	1 524	1.19 (0.31)	0.96	1.15	1.34
All	8 294	1.19 (0.30)	0.98	1.15	1.34
Women					
18–24	1 328	1.36 (0.28)	1.15	1.32	1.54
25–34	2 969	1.41 (0.33)	1.18	1.39	1.61
35–44	1 222	1.40 (0.34)	1.15	1.37	1.58
45–54	862	1.46 (0.37)	1.20	1.44	1.70
55–64	761	1.43 (0.37)	1.18	1.37	1.61
65–74	1 388	1.38 (0.36)	1.13	1.34	1.58
All	8 530	1.41 (0.34)	1.18	1.37	1.61
Total	16 824	1.30 (0.34)	1.06	1.25	1.50

was in the high-risk category (greater than 6.2 mmol/L). The percentage of both men and women with total cholesterol above levels of 5.2 and 6.2 mmol/L increased with age. The proportion of men with total cholesterol levels above 5.2 mmol/L increased rapidly from 14% in the 18–24 age group to 58% for the 35–44 age group and 65% for the 45–54 age group. The proportion of women at moderate and high risk increased more slowly up to age 44, then, coinciding with menopause, the prevalence increased markedly in the succeeding three decades, reaching 80% in the 65–74 age group.

In men, the prevalence of elevated plasma triglycerides increased gradually until the fifth decade and decreased thereafter (Table 6). In contrast, the prevalence in women was only 5% to 7% below age 44, then, coinciding with menopause, increased abruptly to 22% for ages 55 to 64.

In men, the prevalence of LDL-cholesterol at moderate- and high-risk levels (3.4 mmol/L and over) increased markedly between ages 18 and 44, whereas among women the prevalence increased sharply only after age 44 (Table 7). In total, 40% of the men and 32% of the women had an elevated LDL-cholesterol level equal to or greater than 3.4 mmol/L, and 15% had levels above 4.0 mmol/L.

The prevalence of high-risk HDL-cholesterol levels (below 0.9 mmol/L) was 13% in men and only 4% in women (Table 8). Only 32% of men were in the lowest-risk range (above 1.3 mmol/L) versus 60% of women.

Of both men and women in the desirable range for total cholesterol, 89% to 100% also had LDL-cholesterol levels below 3.4 mmol/L (Table 9). In the high-risk total cholesterol range, 94% to 100% also had LDL-cholesterol levels greater than 3.4 mmol/L. Thus, in the low- and high-risk ranges for total cholesterol, there was agreement in risk classification between total and LDL-cholesterol. However, for subjects of all ages in the moderate-risk group, about 35% had an LDL-cholesterol level below 3.4 mmol/L. In this range for total cholesterol, signifi-

Table 5: Distribution of subjects by total plasma cholesterol level by sex and age

	Total plasma cholesterol level; mmol/L; % of subjects		
Sex; age, yr	< 5.2	5.2–6.1	≥ 6.2
Men			
18–24	86	11	3
25–34	66	26	8
35–44	42	36	22
45–54	35	32	33
55–64	39	36	25
65–74	36	40	25
All	52	30	18
Women			
18–24	82	14	4
25–34	77	18	5
35–44	69	23	8
45–54	40	43	17
55–64	20	43	38
65–74	20	36	44
All	57	27	16
Total	55	29	17

Table 6: Distribution of subjects by plasma triglyceride level by sex and age

	Plasma triglyceride level; mmol/L; % of subjects	
Sex; age, yr	< 2.3	≥ 2.3
Men		
18–24	91	9
25–34	88	12
35–44	78	22
45–54	68	32
55–64	74	26
65–74	79	21
All	80	20
Women		
18–24	95	5
25–34	95	5
35–44	93	7
45–54	87	13
55–64	78	22
65–74	79	21
All	89	11
Total	85	15

Table 7: Distribution of subjects by LDL-cholesterol level by sex and age

	LDL-cholesterol level; mmol/L; % of subjects		
Sex; age, yr	< 3.4	3.4–4.0	≥ 4.1
Men			
18–24	88	10	3
25–34	70	21	10
35–44	53	27	20
45–54	43	31	26
55–64	47	32	21
65–74	45	29	26
All	60	24	16
Women			
18–24	87	10	3
25–34	83	12	5
35–44	76	17	7
45–54	58	25	17
55–64	39	28	33
65–74	32	28	40
All	67	18	14
Total	63	21	15

cant additional information is obtained by calculating LDL-cholesterol. Nevertheless, determining LDL-cholesterol in the low-risk cholesterol range identifies up to 11% of subjects who are at risk because of high LDL-cholesterol and who need further investigation and treatment based on the current guidelines.

Cross-tabulation of total cholesterol and HDL-cholesterol levels showed the additional information obtained by estimating HDL-cholesterol (Table 10). An appreciable proportion of subjects of all ages had HDL-cholesterol below 0.9 mmol/L. Within each level of total cholesterol this proportion was about 13% for men and 4% for women.

When levels of plasma triglycerides and HDL-cholesterol were cross-tabulated (Table 11), the percentage of men with HDL-cholesterol below 0.9 mmol/L was equally divided between the two triglyceride ranges. The percentages were lower for women than for men, but were also equally divided between the two ranges. However, the proportions with low HDL-cholesterol level were higher in the group with higher triglyceride levels, 35% for men and 18% for women compared with only 7.5% for men and 2.2% for women in the lower triglyceride range.

For both men and women, there was a positive association between elevated total plasma cholesterol and the prevalence of high blood pressure, smoking and obesity (Table 12). In men with high cholesterol levels, a slightly increased proportion were sedentary, but this was not evident for women. The prevalence of self-reported diabetes mellitus was not associated with plasma cholesterol level.

Table 8: Distribution of subjects by HDL-cholesterol level by sex and age

	HDL-cholesterol level; mmol/L; % of subjects		
Sex; age, yr	< 0.9	0.9–1.2	≥ 1.3
Men			
18–24	9	56	35
25–34	11	56	33
35–44	15	53	32
45–54	15	60	25
55–64	15	50	35
65–74	15	55	30
All	13	55	32
Women			
18–24	3	41	56
25–34	4	33	63
35–44	4	35	61
45–54	4	33	64
55–64	3	37	60
65–74	5	40	55
All	4	36	60
Total	8	45	46

Discussion

Response rate

The percentage of subjects in the total sample from whom an 8-hour fasting specimen was obtained (65%) is within the range of that from other comparable studies. Some reported response rates for 12-hour fasting specimens are 50% for HANES II,[16] 74% for the Lipid Research Clinics Prevalence

Table 9: Distribution of individuals by total plasma cholesterol and LDL-cholesterol levels by sex and age

	Total plasma cholesterol level; mmol/L; % of subjects					
	< 5.2		5.2–6.1		≥ 6.2	
Sex; age, yr	LDL < 3.4	LDL ≥ 3.4	LDL < 3.4	LDL ≥ 3.4	LDL < 3.4	LDL ≥ 3.4
Men						
18–24	84	2	3	8	0	3
25–34	64	3	6	20	0	7
35–44	41	2	11	25	0	20
45–54	32	4	10	23	2	30
55–64	38	1	9	28	0	24
65–74	34	2	10	29	0	24
All	51	2	8	22	0	16
Women						
18–24	81	1	6	8	0	4
25–34	76	2	7	10	0	5
35–44	67	2	9	15	0	7
45–54	39	1	19	24	0	17
55–64	20	0	19	24	0	37
65–74	19	0	13	24	0	43
All	56	1	11	16	0	15
Total	53	2	10	19	0	16

Study[17] and 69% for the Toronto–Hamilton Lipid Research Clinics Survey of an industrial population.[18]

There is a possibility of bias due to selective response if determinants of lipids levels are associated with factors that determine attendance at the clinic and fasting status. In the provincial heart health surveys, the characteristics of nonparticipants in the interview were not ascertained; therefore, it is not possible to assess the potential impact of the response bias. However, the impact of non-response is likely to result in underestimation of the level of risk (see paper on survey methods and data analysis, Tables 2 and 3, page 1973).

Comparison with other surveys

Data from the nine provincial heart health surveys reported in this paper are consistent with those of other studies in that they show appreciable differences in the mean values of blood lipids by sex and by age.

Table 10: Distribution of subjects by total plasma cholesterol and HDL-cholesterol levels by sex and age

	Total plasma cholesterol level; mmol/L; % of subjects					
	< 5.2		5.2–6.1		≥ 6.2	
Sex; age, yr	HDL < 0.9	HDL ≥ 0.9	HDL < 0.9	HDL ≥ 0.9	HDL < 0.9	HDL ≥ 0.9
Men						
18–24	6	80	2	9	0	3
25–34	7	60	3	22	1	7
35–44	6	35	6	31	3	19
45–54	3	31	5	27	7	27
55–64	7	32	6	30	3	22
65–74	7	29	5	34	3	22
All	6	46	4	25	3	15
Women						
18–24	2	80	0	14	0	4
25–34	2	75	1	16	0	5
35–44	2	66	1	22	0	8
45–54	2	38	2	42	0	17
55–64	0	20	1	42	2	36
65–74	2	18	2	35	2	42
All	2	54	1	26	1	15
Total	4	50	3	26	2	15

Table 11: Distribution of subjects by plasma triglyceride and HDL-cholesterol levels by sex and age

	Plasma triglyceride level; mmol/L; % of subjects			
	< 2.3		≥ 2.3	
Sex; age, yr	HDL < 0.9	HDL ≥ 0.9	HDL < 0.9	HDL ≥ 0.9
Men				
18–24	6	85	3	7
25–34	6	82	5	7
35–44	7	71	8	14
45–54	5	63	10	22
55–64	7	67	8	18
65–74	8	71	7	14
All	6	74	7	13
Women				
18–24	2	93	1	4
25–34	3	92	1	4
35–44	2	90	2	5
45–54	2	85	2	11
55–64	0	78	2	20
65–74	2	76	2	19
All	2	87	2	9
Total	4	81	4	11

These results may be compared with the Lipid Research Clinics (LRC) population studies carried out between 1972 and 1978, which used the same methods.[17-20] Mean values for total cholesterol for men in the present study compared with employed men from Toronto and Hamilton are about the same up to age 34 and slightly higher thereafter. For women, the mean values are similar to those of women not taking oral contraceptives in the LRC population study.[20] The present study did not attempt to separate users of sex hormones from non-users. The triglyceride levels in the present study tend to be slightly higher in both sexes compared with the LRC survey.[18,20] Mean LDL-cholesterol levels are the same[18] or slightly lower.[19] Mean plasma HDL-cholesterol values for men are about the same as those of the LRC population, but for women the values in this study are generally lower in all decades. In the United States there has been a decline in total cholesterol levels in the last 10 to 20 years.[21-23] We do not have data in Canada to make valid comparisons of mean values of total cholesterol over time, but the above comparisons provide no suggestion of a decline in cholesterol levels in the last two decades.

Reference values by age and sex

Total plasma cholesterol

Data from the provincial heart health surveys provide evidence that hypercholesterolemia begins early in life for men with a steady increase starting in the third decade of life; for women this increase is delayed until the fifth decade, around the time of menopause. These trends are in keeping with well-known mortality statistics, which show that CHD becomes the primary cause of death for men by the fourth decade and for women by the fifth decade. The increase with age in total plasma cholesterol, LDL-cholesterol and triglyceride concentrations seen in this study has been observed in other populations.[17,24-27] This increase in lipid levels with age is characteristic of industrialized countries. Diets rich in saturated fats and dietary cholesterol and lifestyles that predispose people to obesity tend to raise plasma lipid levels.[27-29]

Mean plasma cholesterol levels for women were lower than those for men until the age of menopause, at which point they surpassed the mean values of men. This is consistent with other studies.[17,18,20,30] It has been postulated that the sudden rise in plasma cholesterol concentration at the time of menopause is probably due to loss of estrogens and consequent decrease in LDL receptor activity.[27]

Triglycerides

Mean plasma triglyceride values increased with age in both men and women. This is probably associated with increasing prevalence of overweight with advancing age[30] (see paper on obesity, pages 2009-2019). Interpretation of the reference triglyceride values by themselves is complicated by the lack

Table 12: Relation of total plasma cholesterol level and other risk factors (age standardized to the 1986 Canadian population)

	Total cholesterol level; mmol/L; % of subjects*		
Risk factor†	< 5.2	5.2–6.1	≥ 6.2
Men			
High blood pressure	13 (4619)	18 (2480)	18 (1249)
Smoking	27 (4618)	26 (2479)	35 (1249)
Body mass index ≥ 27	31 (4588)	40 (2461)	45 (1237)
Sedentary	34 (4615)	39 (2479)	41 (1248)
Diabetes	4 (4174)	4 (2259)	4 (1149)
Women			
High blood pressure	12 (5140)	13 (2141)	15 (1290)
Smoking	26 (5140)	28 (2141)	33 (1289)
Body mass index ≥ 27	25 (5091)	32 (2109)	38 (1268)
Sedentary	34 (5138)	35 (2141)	35 (1289)
Diabetes	5 (4633)	6 (1939)	5 (1176)

*Sample sizes are in parentheses.
†High blood pressure = diastolic ≥ 90 mm Hg or on treatment; smoking = one or more cigarettes every day; sedentary = leisure-time physical activity less than once a week during the last month; diabetes = self-reported.

of complete understanding of the role of triglycerides in the development of atherosclerotic disease. An elevation of triglycerides typically reflects an increase in very low density lipoprotein (VLDL) and VLDL remnant lipoproteins, which include the intermediate density lipoproteins. Elevation of VLDL is often associated with one or more other risk factors, including decreased HDL-cholesterol, abnormal LDL, obesity, impaired glucose tolerance, hyperinsulinemia and hypertension.[31] Thus it is clear that triglycerides serve in part as a surrogate for a complex, multifactorial risk profile.

The interdependence of triglyceride level and other lipid and lipoprotein fractions does not detract from its value as an index of coronary disease risk.[32] Its quantification is necessary for the estimation of LDL-cholesterol. Assessment of triglyceride level on an individual basis as a risk factor is more difficult than assessment of total cholesterol level. It has been proposed that the biologic variability inherent in plasma triglyceride levels may explain the fact that statistical analyses on prospective studies may have underestimated its effect on CHD risk.[31] For some specific population groups, including postmenopausal women, older men and subjects with low HDL-cholesterol level, triglyceride level appears to play an independent role in the development of CHD.[33]

LDL-cholesterol

LDL-cholesterol is recognized as the major atherogenic lipoprotein fraction. Reduction of LDL-cholesterol levels in the Lipid Research Clinic Coronary Primary Prevention Trial led to significant reduction in the incidence of CHD.[34,35] Some evaluation and treatment guidelines for high blood cholesterol make LDL-cholesterol level the goal for treatment and for determining whether intensive dietary counselling and drug therapy are indicated.[1,2] The concordance between plasma LDL and total cholesterol as CHD risk indices is explained in part by the composition of plasma lipoproteins. LDL-cholesterol correlates closely with total plasma cholesterol because the LDL fraction normally contains about three-quarters of the plasma cholesterol (3 mmol/L). The HDL contains only about 20% of cholesterol (1 mmol/L) and VLDL only 0.2 mmol/L.

The increasing mean values of LDL-cholesterol with advancing age may be related to the increasing prevalence of overweight in older men and women[30] (see the paper on obesity, pages 2009–2019).

HDL-cholesterol

HDL-cholesterol has been found to be a negative risk factor or protective CHD factor[36–40] well into advanced age.[41–43] In all age groups, mean HDL-cholesterol level was lower in men than in women, a finding that has been observed in other population studies.[16,30,36] This pattern coincides with the fact that the incidence of CHD in women is lower than in men and that mortality rates from this cause lag behind those of men by about 10 years.[44–46]

HDL-cholesterol is negatively associated with overweight and smoking, and positively associated with moderate alcohol consumption[16,30,47] and physical activity.[30] The interrelations among these factors may be clarified in future research using the provincial heart health surveys database.

Prevalence of abnormal lipid levels

The trends in mean total plasma cholesterol levels with age and sex (Table 1) and the distribution of the population by cholesterol level (Table 5) indicate that about one in two adults is at increased risk for CHD due to elevated blood cholesterol. Nearly one-third of adults have moderate-risk blood cholesterol levels and one in six have levels in the high-risk range. These data suggest the need for complementary strategies to address the cholesterol issue. Individuals at the higher levels of risk stand to benefit most from individual approaches to lower their blood cholesterol. However, at the community and population levels, health promotion approaches targeted to the moderate-risk group are likely to be the most effective. Rose[48] has provided an elegant epidemiological argument that shows that most cases of CHD due to elevated blood cholesterol originate in people in the moderate-risk categories.

Prevalence of dyslipidemia begins earlier in life for men with a gradual increase starting in the third decade of life; for women this is delayed until the fifth decade, around the time of menopause. These trends are in keeping with the well-known mortality statistics for CHD showing that CHD becomes the primary cause of death for men by the fourth decade and for women by the sixth decade. These trends also indicate that to be effective, primary prevention of atherosclerotic disease must be started early in life, at least by the second or third decade. This applies to medical management of high-risk patients and to the population at large for public health programs.

Lipid fractions in the characterization of risk

Over one-third of men and women have LDL-cholesterol values exceeding 3.4 mmol/L. Whereas a high total plasma cholesterol level is usually a fairly good surrogate for an elevated LDL-cholesterol level this is not always the case (Table 9). In the moderate-risk range for total cholesterol, 30% had a low-risk LDL-cholesterol level and would not have re-

quired treatment, provided that triglyceride and HDL-cholesterol levels were also low risk. Occasionally in the very high or very low total plasma cholesterol ranges LDL-cholesterol determination would change the decision to treat the subject. Therefore, determining LDL-cholesterol is advisable in every subject before a correct and final decision can be made about the need for treatment.

There is value in measuring HDL-cholesterol to identify subjects at risk for CHD regardless of the level of total plasma cholesterol (Table 10) or the level of plasma triglyceride (Table 11). However, in the group of subjects with high triglyceride levels there is a much higher prevalence of low HDL-cholesterol levels — 35% for men and 18% for women compared with only 7.5% and 2.2%, respectively, in the low triglyceride group. As discussed above, subjects with elevated plasma triglycerides and low HDL-cholesterol are at high risk.[31-33]

Presence of other risk factors

Atherosclerosis is recognized as a disease with multiple causes or risk factors. Furthermore, the risk factors are known to coexist (e.g., increasing age, obesity and high blood pressure [see papers on obesity and high blood pressure], hypercholesterolemia and high blood pressure,[5] and age and plasma cholesterol concentration). It is not surprising that the present survey (Table 12) shows increasing age-adjusted prevalence of high blood pressure, smoking and overweight with plasma cholesterol level. Generally, all of these risk factors are more prevalent with increasing age. They are more prevalent in men than in women, but after menopause women assume the same or even higher prevalence of these risk factors than men.

This coexistence of risk factors speaks eloquently in favour of physicians examining their patients for all CHD risk factors. Moderate elevation of several risk factors may place an individual at high risk of CHD.[6,45] Individual coronary risk factors can occur in isolation at any age in either sex. In the absence of other risk factors, 39% of men and 35% of women were at risk because of plasma cholesterol levels greater than 5.2 mmol/L (data not shown). The results attest to the need for integrated multifactorial public health approaches to cardiovascular disease (CVD) prevention. Projections of the impact of risk factor modifications on death from any cause indicate that the percent reduction from a multifactorial intervention with moderate reductions in the prevalence of the three major risk factors would be equivalent to the eradication of any one of them.[49]

Conclusions

The high prevalence of CHD risk factors in all age groups of both sexes in this survey of the Canadian population strongly supports a balanced public health approach aimed at the population at large and the groups at higher risk identified in the provincial heart health surveys. There is a need for education programs on cholesterol and nutrition that provide consistent messages to the public. They should include specific information on blood cholesterol as a risk factor and advice on how to comply with the nutrition recommendations released by Health and Welfare Canada.[50] An effective nutrition strategy is the cornerstone of a population approach to the cholesterol issue.

The results presented in this paper and the burgeoning knowledge of the influence of diet on plasma lipoprotein patterns[27] make it advisable to complement the database on CVD risk factors with nutritional survey data. This would help explain the trends in lipid CHD risk factors and guide development and evaluation of CVD policies and programs.

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