Original Article

Influence of fish consumption on the distribution of serum cholesterol in lipoprotein fractions: comparative study among fish-consuming and non-fish-consuming populations

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The objective of this study was to investigate serum lipoprotein levels in order to assess cardiovascular disease (CVD) risk factors between fish-consuming populations and non-fish-consuming populations, as it has been speculated that fish intake reduces CVD risk. A representative sample of one thousand subjects (529 men and 471 women) were selected, with ages ranging from 20 to 70 years, from 40 villages belonging to fish-consuming (500) or non-fish-consuming (500) populations. Serum lipoprotein lipids such as total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C) were analysed biochemically using standard procedures. The ratios of TC : HDL-C and LDL-C : HDL-C were computed. Mean values of serum LDL-C and the ratios of LDL-C : HDL-C and TC : HDL-C were significantly lower and HDL-C levels were higher in fish-consumers than in non-fish-consumers. The concentrations of HDL-C decreased with increasing age, while the reverse was true for LDL-C and for the LDL-C : HDL-C and TC : HDL-C ratios. There were significant sex differences for certain age groups in both of the population groups. The 5th, 50th and 95th percentile cut-off values for these parameters were lower in fish-consumers than in non-fish-consumers. The prevalence of individuals at risk of CVD because of low HDL-C (<35 mg/dL), high LDL-C (>130 mg/dL) and their atherogenic ratios (LDL-C : HDL-C > 3.5 and TC : HDL-C > 4.5) was significantly greater in non-fish-consumers. This study highlights that the fish-consuming population had a lower atherogenic risk than the non-fish-consuming population. The intake of fish may have substantial implications for public health and health economy by decreasing the risk of CVD. However, more studies are warranted to better define the mechanisms of cardioprotection by dietary fish and fish oils.

Key words: cardiovascular disease risk factors, fish consumption, India, long-chain n-3 polyunsaturated fatty acids, serum lipoprotein lipids, Tirupati.

Introduction

Cardiovascular disease (CVD) is the most frequent cause of morbidity and mortality not only in developed nations but also in developing nations like India.[1,2] India is experiencing a process of rapid epidemiological transition in terms of patterns of health and disease as communities transform their social and economic structures.[3] There have been marked changes in the diet and lifestyle characteristics of Indian people, resulting in a rapid emergence of CVD. An increase in CVD mortality has been documented following the recent acculturation and socioeconomic development and the burden of disease is predicted to increase over the next 20 years.[4–6] The people living in urban India have CVD rates similar to Indians living overseas, having the highest rates reported for Indian people.[7,8] The prevalence of CVD in rural areas is half that of urban India.[7,9] However, the overseas Indian rates are double those of the United States and four-fold higher than those of rural China and Japan.[10]

The role of blood lipids and lipoproteins in predicting morbidity and mortality from CVD has been well established.[11,12] Cholesterol and its lipoprotein subfractions, such as high-density lipoprotein cholesterol (HDL-C) and low-density lipoprotein cholesterol (LDL-C), have received considerable attention.[13–15] The significance of elevated LDL-C is identified as the major atherogenic plasma lipoprotein.[16–18] Variations in LDL-C concentrations account for a large part of the variance in CVD incidence within high risk populations.[17] Prospective epidemiological studies have shown that low plasma HDL-C is an independent risk factor

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for CVD.[19,20] Further, studies have shown that the ratios of LDL-C : HDL-C and total cholesterol (TC) : HDL-C are the strongest determinants of overall risk evaluation for CVD.[13,21]

Changes in the dietary patterns of populations are considered to be related to trends in CVD risk.[22] Dietary factors are suggested to have a significant impact on such CVD risk factors as hyperlipidemia, hypertension and obesity.[23–25] Japanese people are known to have one of the longest life expectancies and their diet is believed to be the most ideal diet in the world.[26,27] Their low death rate from CVD has been attributed to their high intake of fish and other seafood. Epidemiological studies have revealed a reduced incidence of CVD in populations with a high or moderate fish consumption.[28–30] This has been attributed to the abundance of long-chain n-3 polyunsaturated fatty acids (n-3 LCPUFA) present in fish oils, including eicosapentaenoic acid (EPA; 20:5n-3), docosapentaenoic acid (DPA; 22:5n-3) and docosahexaenoic acid (DHA; 22:6n-3).[31] The hypolipidemic effect of dietary fish oils has received much recognition in both scientific and non-scientific press.[32,33] The dietary n-3 LCPUFA of fish oils exert beneficial effects by reducing platelet aggregation and improving blood lipoprotein profiles. Further, fish/fish oil consumption has been associated consistently with triglyceride-lowering effects. The most consistent effects of n-3 LCPUFA are the reduction of serum cholesterol,[32] triglycerides,[33] very-low density lipoprotein cholesterol (VLDL-C) and LDL-C.[34,35] Further, intake of n-3 LCPUFA increases HDL-C in normal subjects.[36] However, some studies have shown contradictory results regarding the anti-atherogenic effects of n-3 LCPUFA from fish and fish oils.[37,38]

There are limited studies describing the dietary habits of Indian populations in relation to CVD risk profiles. The present study was conducted with the objective to investigate atherogenic risk factors using lipoprotein lipids of healthy subjects from a habitual fish-consuming population and a similar non-fish-consuming group.

Materials and methods

The present study was a cross-sectional evaluation of coastal villages of the Nellore district, situated in the south-eastern part of the state of Andhra Pradesh, India. The district of Nellore extends from 13°3′N to 15°10′N in latitude and from 79°5′E to 80°15′E in longitude on the south-east coast. The study area was selected by random sampling from 40 rural villages at a distance of 10–140 km from the headquarters of the district, Nellore town. All of the villages were located in similar geographical, environmental and cultural settings and represented average living standards. A total of 1000 healthy subjects aged 20–70 years were studied, matched for sex and age. The survey participants were divided into fish-consuming and non-fish-consuming populations based on their history of regular fish consumption. There were 500 subjects (266 men and 234 women) in the fish-consuming group and 500 subjects (263 men and 237 women) in the non-fish-consuming group. All of the subjects gave their informed consent prior to participation. Subjects with a history of non-communicable disease and medication were excluded.

Subjects were selected on the basis of their habitual fish consumption during the previous years. They were asked to categorise whether their habitual intake included either marine or freshwater fish. Those who ate a minimum of three fish meals per week were placed in the fish-consuming group. The frequency of fish consumption ranged between 3 and 7 meals per week with an average of 20–30 g/day. Those who had not consumed fish in their lifetime were classified as being of the non-fish-consuming population. The main occupations of these population groups were fisherman, agriculturalists and labourers. Other sociocultural habits of the study populations were almost similar.

Demographic data were recorded on such factors as age, sex and birthplace, and on the level and type of physical and lifestyle activities. Home visits were undertaken and the 24 h recall method was used to assess the dietary intake of each individual in a 20% subsample. The amounts of raw foods were calculated from the cooked food consumed by an individual index person using volumetric conversions. Total individual calories and nutrient intake were computed from the Indian food tables and details pertaining to the sampling procedures, as well as the nutrient intake of these populations, have been reported previously.[39,40]

Venous blood samples were taken in the morning hours and serum was separated and stored at – 20°C until the analysis was carried out. The fatty acid profiles of serum phospholipids were determined. The lipids were extracted into chloroform/methanol, separated by thin-layer chromatography, isolated and methylated (*trans*-methylation catalysed by boron trifluoride). The fatty acid concentration of the samples was measured by gas-chromatographic analysis and the relative concentrations of each fatty acid was expressed as a percentage of the total fatty acids. Detailed methods and results on serum fatty acids and lipids (TC, triglycerides and phospholipids) are published elsewhere.[39–41]

The level of HDL-C in serum was measured after precipitation of chylomicrons, LDL and VLDL with buffered phosphotungstic acid and magnesium chloride, using the same method as that for total cholesterol (TC).[42] The LDL-C concentration was calculated according to the Friedwalds' equation:

$$\text{LDL-C} = \text{TC} - \text{HDL-C} - (\text{triglycerides} \div 5)$$

This formula was considered reliable for the subjects whose triglycerides levels were < 400 mg/dL.[43] The following cut-off points for elevated lipoproteins were determined as risk factors using the criteria of the American National Cholesterol Education Program:[13] HDL-C, < 3 5 mg/dL; LDL-C, > 130 mg/dL; LDL-C : HDL-C, > 2.0; and TC : HDL-C, 4.5.[44]

The statistical measures used were mean, median, standard deviation, percentage and percentile. The differences in mean values between men and women, and between population groups, were analysed by the Student's *t*-test. The χ^2-test was performed in order to demonstrate any difference in the

prevalence of lipoproteinemia risk markers between groups. A difference of $P < 0.05$ was accepted as significant.

Results

Table 1 shows the distribution of the study populations according to gender and age group. Among the fish-consuming population, the largest proportion (21%) was aged 41–50 years and the smallest proportion (18%) was aged 31–40 years. As for the non-fish-consuming population, 23% of them were aged between 51 and 60 years, while 18% were in the age group of 61–70 years.

The mean concentrations of serum lipoproteins among fish-consuming and non-fish-consuming populations are presented by age and sex in Table 2. For both of the population groups, the mean values were almost similar for age (46.5 *vs* 46.0 years), body weight (51.4 *vs* 51.8 kg), height (167 cm) and body-mass index (18.6 *vs* 18.7 kg/m^2). The HDL-C concentrations were decreased consistently with age in both of the sexes and populations. Mean HDL-C levels were significantly higher in fish-consuming subjects than in non-fish-consuming subjects. A difference between the sexes was significant only in the age group of 21–30 years ($P < 0.05$) among non-fish-consumers. The proportion of HDL-C present in TC was expressed as HDL%, which showed a decreasing trend as age advanced. The HDL% was greater in both sexes among the fish-consumers, compared with the non-fish-consumers. The fish-consuming group had significantly higher favourable HDL-C levels among men and women than the non-fish-consuming population of the same age group.

As expected, the mean concentrations of LDL-C as well as LDL proportion to TC (LDL%) were progressively increased with age in both of the sex and population groups. The increase in LDL-C with age for men was smaller (43.9 mg/dL and 53.8 mg/dL), while it was greater for women (48.2 mg/dL and 61.6 mg/dL). Fish-consuming men and women had significantly lower levels of LDL-C (95.9 *vs* 103.6 mg/dL and 96.3 *vs* 101.4 mg/dL, respectively) than non-fish-consumers. Women had lower LDL-C concentrations than men in younger age groups (21–30 and 31–40 years), while in older age groups, women dominated over men. Significant variation was found between the sexes in the age group of 31–40 years in the fish-consuming population ($P < 0.01$). The differences between population groups were commonly significant among men and women in the age groups 21–30, 61–70 and total years.

Table 1. Distribution of study populations

Age (years)	Fish-consuming population			Non-fish-consuming population		
	Men *n* (%)	Women *n* (%)	Total *n* (%)	Men *n* (%)	Women *n* (%)	Total *n* (%)
21–30	56 (11)	46 (09)	102 (20)	46 (09)	49 (10)	95 (19)
31–40	50 (10)	42 (08)	92 (18)	47 (09)	48 (10)	95 (19)
41–50	57 (11)	54 (11)	111 (21)	54 (11)	51 (10)	105 (21)
51–60	53 (11)	48 (10)	101 (20)	68 (13)	49 (10)	117 (23)
61–70	50 (10)	44 (09)	94 (19)	48 (10)	40 (08)	88 (18)
Total	266 (53)	234 (47)	500 (100)	263 (52)	237 (48)	500 (100)

Table 2. Serum lipoprotein lipid concentrations (mg/dL) by age and sex among fish-consuming and non-fish-consuming populations

Age (years)	Fish-consuming population HDL-C (mg/dL)	Non-fish-consuming population HDL%	Fish-consuming population LDL-C	Non-fish-consuming population LDL%
Men				
21–30	48.8 ± 5.8 (32.8)	46.7 ± 4.8 (31.2)	72.3 ± 18.0 (51.7)	80.8 ± 16.4 (54.0)**
31–40	48.2 ± 4.7 (29.0)	46.3 ± 4.9 (28.4)*	90.4 ± 23.2 (54.5)	89.1 ± 17.1 (54.7)
41–50	48.2 ± 5.5 (28.4)	45.1 ± 4.3 (25.9)**	93.8 ± 18.2 (55.3)	99.5 ± 21.7 (57.3)
51–60	47.7 ± 6.1 (24.9)	44.4 ± 5.3 (22.7)**	109.6 ± 20.1 (57.2)	114.2 ± 26.3 (58.3)
61–70	48.7 ± 5.8 (24.3)	44.2 ± 4.3 (21.2)*	116.2 ± 20.7 (58.1)	129.0 ± 31.9 (62.0)**
Total	47.7 ± 5.7 (27.5)	45.2 ± 4.9 (25.2)**	95.9 ± 25.0 (55.4)	103.6 ± 28.8 (57.7)**
Women				
21–30	46.1 ± 5.7 (34.2)	48.7 ± 5.2 (32.7)*†	69.9 ± 14.8 (51.9)	77.4 ± 20.8 (52.0)**
31–40	48.7 ± 4.9 (31.4)	47.5 ± 5.7 (30.4)	80.3 ± 13.2 (52.6)††	83.1 ± 20.5 (53.3)
41–50	47.2 ± 3.9 (27.5)	44.2 ± 4.2 (25.2)**	95.0 ± 19.8 (55.4)	98.8 ± 18.8 (56.3)
51–60	47.2 ± 5.8 (24.3)	44.5 ± 4.4 (22.5)*	111.9 ± 24.2 (57.8)	115.2 ± 26.9 (58.3)
61–70	47.6 ± 5.5 (23.0)	43.5 ± 4.5 (19.7)**	123.7 ± 22.4 (59.7)	139.0 ± 31.8 (63.1)**
Total	47.3 ± 5.2 (27.5)	45.7 ± 5.2 (25.7)**	96.3 ± 27.5 (56.0)	101.4 ± 32.2 (57.0)**

Figures in parentheses denote the proportion of lipoprotein to total cholesterol. †Significantly different between sexes for the same age group. *Significantly different between population groups for the same age group. Statistical significance (Student's *t*-test): †/*0.05 > *P* > 0.01; ††/**0.01 > 0.001. HDL%, proportion of high-density lipoprotein to total cholesterol; HDL-C, high-density lipoprotein cholesterol; LDL%, proportion of low-density lipoprotein to total cholesterol; LDL-C, low-density lipoprotein cholesterol.

The age-specific means for the values of the LDL-C : HDL-C and TC : HDL-C ratios are given as atherogenic indices in Table 3. The distribution of these indices showed a pattern similar to that of the LDL-C distribution. There was an age-dependent increase in the ratios of LDL-C : HDL-C for both of the sexes and the population groups. The mean ratios of LDL-C : HDL-C were 2.03 and 2.05 for the fish-consuming men and women, respectively, as compared to 2.32 and 2.26 for the non-fish-consuming men and women. The mean LDL-C : HDL-C ratio was significantly lower among the fish-consuming men for the 21–30 year ($P < 0.05$), 41–50 year, 51–60 year, 61–70 year and total ($P < 0.01$) age groups than among the non-fish-consumers. Significant differences were observed for women in the 41–50 year ($P < 0.05$), 61–70 year and total years ($P < 0.01$) age categories. Similarly, the ratios of TC : HDL-C were increased with advanced age for both of the population groups.

The normal limits of serum lipoproteins in either of the populations did not show normal distribution curves. Instead, they were skewed toward the lower level of mean values among both the fish-consuming and non-fish-consuming populations (Table 4). The median (50th percentile) values were marginally lower than their respective mean values. The median HDL-C and LDL-C values were 47.1 mg/dL and 93.9 mg/dL, respectively, for the fish-consuming population and 44.9 mg/dL and 98.1 mg/dL, respectively, for the non-fish-consuming population. The 5th, 50th and 95th percentiles for HDL-C and LDL-C were lower in the fish-consuming group than in the corresponding non-fish-consuming group. The cut-off values at the 95th percentile were 54.1 mg/dL for HDL-C and 114.2 mg/dL for LDL-C among the fish-consuming men, and 56.9 mg/dL for HDL-C and 145.6 mg/dL for LDL-C for the fish-consuming women. Among the non-fish-consuming group, the men had a HDL-C value of 52.6 mg/dL and a LDL-C value of 164.5 mg/dL, and the women had a HDL-C value of 53.4 mg/dL and a LDL-C value of 170.5 mg/dL.

Using the criteria of National Cholesterol Education Program (NCEP)[13,44] for North America, the prevalence of various at-risk categories for HDL-C, LDL-C and the atherogenic ratios among the fish-consuming and non-fish-consuming populations are shown in Table 5. Among the

Table 3. Ratios of LDL-C : HDL-C and total cholesterol : HDL-C by age and sex among fish-consuming and non-fish-consuming populations

Age (years)	LDL-C : HDL-C		TC : HDL-C	
	Fish-consuming population	Non-fish-consuming population	Fish-consuming population	Non-fish-consuming population
Men				
21–30	1.56 ± 0.35	1.75 ± 0.40*	3.10 ± 0.37	3.22 ± 0.37
31–40	1.90 ± 0.55	1.95 ± 0.43	3.47 ± 0.62	3.55 ± 0.51
41–50	1.98 ± 0.47	2.23 ± 0.54**	3.56 ± 0.56	3.89 ± 0.60**
51–60	2.31 ± 0.41	2.61 ± 0.61**	4.05 ± 0.47	4.45 ± 0.77**
61–70	2.42 ± 0.51	2.94 ± 0.71**	4.16 ± 0.63	4.74 ± 0.86**
Total	2.03 ± 0.55	2.32 ± 0.71**	3.66 ± 0.66	4.01 ± 0.87**
Women				
21–30	1.52 ± 0.27	1.61 ± 0.52††	2.93 ± 0.23†	3.08 ± 0.60
31–40	1.66 ± 0.33†	1.77 ± 0.47†	3.15 ± 0.35††	3.31 ± 0.51
41–50	2.03 ± 0.48	2.26 ± 0.47*	3.66 ± 0.55	4.00 ± 0.56**
51–60	2.40 ± 0.57	2.61 ± 0.63	4.16 ± 0.53	4.46 ± 0.70*
61–70	2.63 ± 0.52†	3.22 ± 0.77**	4.39 ± 0.60	5.09 ± 0.81†**
Total	2.05 ± 0.52	2.26 ± 0.81**	3.66 ± 0.73	3.95 ± 0.96**

Values are given as mean ± SD. †Significantly different between sexes for the same age group. *Significantly different between population groups for the same age group. Statistical significance (Student's *t*-test): †/*0.05 > *P* > 0.01; ††/**0.01 > 0.001. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol.

Table 4. Percentile cut-off points for lipoprotein lipids among fish-consuming and non-fish-consuming populations

Lipoprotein lipid (percentile)	Fish-consuming population			Non-fish-consuming population		
	Men	Women	Total	Men	Women	Total
HDL-C (mg/dL)						
5th	36.7	37.2	37.0	36.1	36.3	36.1
50th†	47.3	46.9	47.1	44.6	45.1	44.9
95th	54.1	56.9	56.9	52.6	53.4	53.4**
LDL-C (mg/dL)						
5th	54.1	53.2	53.8	56.9	54.3	55.8
50th†	94.3	93.4	93.9	99.6	96.5	98.1
95th	114.2	145.6	129.2	164.5	170.5	167.6**

†Fiftieth percentile values are marginally different from mean values. Statistical significance (χ^2-test): **$P < 0.01$. HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol.

Table 5. Prevalence of lipoprotein lipid risk status among fish-consuming and non-fish-consuming populations

Lipoprotein lipid cut-off values	Fish-consuming population						Non-fish-consuming population					
	Men		Women		Total		Men		Women		Total	
	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*
HDL-C (mg/dL)												
< 35 (Low)	14.7	39	14.5	34	14.6	73	17.9	47	17.7	42	17.8	89
36–45 (Medium)	16.9	45	22.6	53	19.6	98	35.0	92	31.2	74	33.2	166
46 < (High)	68.4	182	62.8	147	65.8	329	47.1	124	51.1	121	49.0†	245
LDL-C (mg/dL)												
< 130 (Low)	93.2	232	85.4	200	86.4	432	75.3	198	68.4	162	78.0	360
131–155 (Medium)	5.4	27	11.5	27	10.8	54	17.1	45	21.5	51	19.2	96
156 < (High)	1.7	7	3.0	7	2.8	14	7.6	20	10.1	24	8.8†	44
Atherogenic index 1												
LDL-C : HDL-C (> 3.5)	3.8	10	8.1	9	3.8	19	6.8	18	7.6	23	7.2*	36
Atherogenic index 2												
TC : HDL-C (> 4.5)	4.9	13	4.7	11	4.8	24	4.6	12	15.2	36	9.6*	48

Statistical significance (χ^2-test): †$0.05 > P > 0.01$ (d.f. = 2); *$0.05 > P > 0.01$ (d.f. = 1). HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; TC, total cholesterol.

fish-consumers, only 14.6 and 19.6% had low (<35 mg/dL) and medium (36–45 mg/dL) HDL-C levels, respectively, while 10.8 and 2.8% had high (131–155 mg/dL) and very high LDL-C levels (>155 mg/dL). The corresponding percentages among non-fish-consumers were 17.8, 33.2, 19.2 and 8.8%, respectively. The atherogenic ratios were 7.2% for LDL-C : HDL-C and 9.6% for TC : HDL-C among the non-fish-consumers, but only 3.8 and 4.8% for the corresponding ratios among the fish-consumers. The extent of risk prevalence was higher in women than in men in both populations. The extent of lipoprotein risk status for HDL-C and LDL-C was significantly higher in the fish-consuming group ($P < 0.01$) than in the non-fish-consuming group ($P < 0.01$).

Discussion

The data presented here demonstrate that the fish-consuming population has a favourable lipoprotein profile compared with the non-fish-consuming population. The fish-consuming group have considerably higher HDL-C and lower LDL-C levels and atherogenic ratios than the non-fish-consuming group. A diet rich in fish may therefore play a role in the determination of lipoprotein differences between these diet groups. Experimental and cross-cultural studies have reported that the type of fat consumed induces both atherosclerosis and thrombosis in the aetiology of CVD.[22,45,46] Among the dietary factors, the quantity of fat is a less important, modifiable risk factor for CVD than the quality of fat consumed.[47] The fat content of the diet is reflected in the fatty acid patterns in red blood cells and serum.[48–51] The fish-consuming group were characterised by an increased proportion of n-3 LCPUFA in the serum, mainly due to the accumulation of n-3 LCPUFA, such as EPA, DPA and DHA, to a decreased proportion of n-6 LCPUFA.[28,39] Further, an increase in the n-3 LCPUFA series is negatively correlated with n-6 LCPUFA and the ratio of n-6 : n-3 LCPUFA of fish-consumers is much less (3.21%) than that of non-fish-consumers (14.34%).[39] Because fishing is the main occupational activity of the fish-consuming population, it is not surprising that fish is the main animal-protein source, with almost every subject consuming fish daily. The accumulation of n-3 LCPUFA in the serum phospholipids of the membranes was associated with a reciprocal decrease in the n-6 LCPUFA, especially arachidonic acid (20:4 n-3), due to the inhibitory effect of n-3 LCPUFA in the synthesis of arachidonic acid from linoleic acid (18:2 n-6). When compared with the fish-consuming population, the average per capita fish consumption of the Greenland Eskimos and Japanese fishermen was estimated to be much higher.[27,51–53]

It is now well established that diets rich in fish and fish oils protect against CVD.[50,53] This study confirms previous observations from other countries indicating that fish-consumers have less risk of CVD than non-fish-consumers.[52,54,55] The hypolipidemic effect of dietary fish has been well documented.[56,57] Moreover, previous studies from the Indian region reported that the mean distributions of blood lipids and blood pressures were significantly lower in fish-consuming groups than in non-fish-consuming groups.[40,41]

Although serum total cholesterol is an independent risk factor for premature CVD, its atherogenecity is markedly influenced by the levels of lipoprotein present in cholesterol.[16–18] The levels of lipoprotein present in cholesterol (HDL-C) are greater in fish-consumers, while the levels of LDL-C are lower in comparison to the non-fish-consuming group. The evidence for an association between low HDL-C and CVD is quite strong, playing a pivotal role in the removal of excess cholesterol from the tissues.[19,20] A low content of HDL-C confers a greater risk of CVD compared with a high concentration of serum triglycerides and cholesterol, which is seen in virtually all countries and in both men and women.[58] A diet resulting in serum HDL-C reduction and LDL-C elevation may augment the risk of CVD.

Several studies have documented that fish intake can favourably affect lipoproteins with (higher) HDL-C and

(lower) LDL-C levels.[29,31,33] The overall mean values of HDL-C in fish-consumers were greater than those in non-fish-consumers, despite the non-significant difference in some age groups. In view of the predictive risk status for the proportion of HDL-C in total cholesterol (HDL%), the former group had a relatively lower risk than the latter group. The results of this study are in agreement with those of other epidemiological and clinical studies.[51,52,58,59] However, some studies observed either no effect on HDL-C,[60,61] or reduced HDL-C.[62] The mean LDL-C level among fish-consumers is lower than that among non-fish-consumers, as reported in other studies.[35,36,59,63] Clinical studies have reported that a high intake of fish and fish oils lowers LDL-C,[33,64,65] but this is not true for moderate or lower doses of fish oils.[35,36] In some controlled studies using relatively lower doses of fish oils, no change was reported in LDL-C,[66] while others documented an increased LDL-C level.[67] However, some studies with negative effects of n-3 LCPUFA on LDL-C warrant further controlled clinical investigations.

There were differences between men and women in regard to the lipoprotein levels by age. Overall, LDL-C and the TC : HDL-C and LDL-C : HDL-C ratios increased with age, which was evident in both of the population groups, in accordance with the findings of others.[13] In general, serum concentrations of LDL-C increase with age, contributing to a heightened risk of CVD in older women.[68] This may be due to the cholesterolemic impact of menopause as after menopause, the atherogenic risk markers rise steeply in women and exceed the levels found in men.[2,7] Thus, menopause is associated with a decrease in HDL-C levels and an increase in LDL-C levels.[67,69]

The classification of lipid phenotypes by the measurement of lipoproteins implies that only those with levels above the 95th percentile were considered as abnormal.[70] Hyperlipoproteinemia exists when the concentrations of lipoproteins exceed the upper limits of normal. The percentile cut-off values were relatively lower in fish-consumers than in the non-fish-consuming group. However, the values of normal will vary according to the locality, age, sex distribution and diet of the population under study.[71]

According to the American NCEP guidelines, a serum LDL-C level > 130 mg/dL (3.5 mmol/L) is considered a risk factor for CVD.[13] If the value of the LDL-C : HDL-C ratio is > 3.5, or the TC : HDL-C ratio is > 5.0, then diet therapy to reduce the elevated LDL-C level is advised in order to reduce the risk of CVD.[21] Generally, individuals with a LDL-C level > 130 mg/dL and a HDL-C level < 35 mg/dL (0.9 mmol/L) are used as the index for CVD risk.[72] However, the appropriateness of using cut-off points employed in Western countries to define the risk thresholds for other areas is debatable, and a LDL-C value of < 100 mg/dL is suggested to be ideal for Indian people.[72]

The ratios of LDL-C : HDL-C and TC : LDL-C are frequently used as a measure of atherogenecity. These indicated that the risk of CVD was significantly higher in non-fish-consumers than in fish-consumers. Based on the Framingham Heart Study, these indices are important determinants for assessing CVD, with the risk increasing several-fold when a TC : HDL-C ratio of 4.5 or more is detected.[21,22,73] In the fish-consuming group, the atherogenic TC : HDL-C ratio was 3.8%, and 7.2% in the non-fish-consumers, in excess of the cut-off value of 4.5. This study recorded a LDL-C : HDL-C ratio of 4.8% for the fish-consumers and 9.6% for the non-fish-consumers, both being in excess of the cut-off point of 3.5, which proved to be an important indicator of CVD in population studies.[21]

A number of mechanisms have been suggested for the reduced CVD risk associated with diets rich in fish and n-3 LCPUFA.[33,74] Reduced concentrations of LDL-C and VLDL-C in plasma during fish/fish oil consumption could be attributed to several mechanisms. These include: a favourable lipoprotein lipid profile; reduced synthesis of triglycerides in the liver; an increased rate of catabolism of VLDL due to an increase in the activity of lipoprotein lipase or possibly hepatic lipase; an enhanced clearance rate of LDL from plasma; an increased expression of high-affinity LDL-receptors; and a combination of these potential mechanisms.[33,75]

Conclusion

The results of this study, along with other reports, lend support to the beneficial role of fish consumption on CVD risk factors. These factors include high serum levels of HDL-C and low serum levels of LDL-C, and the values of the LDL-C : HDL-C and TC : HDL-C ratios. The reduction of LDL-C and elevation of HDL-C are significant factors in reducing CVD risk in the fish-consuming group. The prevalence of dyslipoproteinemias and the atherogenic ratios were found to be lower in the fish-consuming compared to the non-fish-consuming group. It could be suggested from this study that fish consumption improves the lipid profile. Further studies are required in order to confirm these results and add more insights to the understanding of cardioprotection. The Indian people are undergoing a process of rapid sociocultural transition associated with lifestyle changes in diet, which can be expected to have an impact on the risk of several degenerative diseases. Clinical trials with expensive pharmacotherapies to prevent CVD have not shown appreciable results, and some have even shown deleterious effects. Dietary measures are therefore considered to be an important aspect in promoting a healthy lifestyle for preventing the country's emerging CVD epidemic in the coming millennium.

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