Fish Consumption and Blood Lipids in Three Ethnic Groups of Québec (Canada)

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ABSTRACT: The purpose of this study was to compare fish intake and plasma phospholipid concentrations of n-3 fatty acids, in particular of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), among representative population samples of Québecers, James Bay Cree, and Inuit of Nunavik (Canada). The relationships between these concentrations and cardiovascular disease (CVD) risk factors were also investigated and compared in the three populations. In 1990–1992, the study subjects had participated in the extensive Santé Québec health surveys conducted in southern Québec, James Bay, and Nunavik. Significant differences in levels of CVD risk factors were found among these three populations. Globally, Inuit showed the lowest risk status for CVD compared with Cree and Québecers, despite the high prevalence of cigarette smoking and obesity. Daily fish intakes varied significantly among the three groups, averaging 13, 60, and 131 g for Québecers, Cree, and Inuit, respectively. Concentrations of EPA + DHA in plasma phospholipids were highest among Inuit (8.0%), second-highest among Cree (3.9%), and lowest among Québecers (1.8%). When the three populations were grouped together, there was a positive association between concentrations of EPA + DHA stratified into quartiles and HDL cholesterol, with a significant relation in quartile 4 (EPA + DHA ≥4.04%). An inverse relation was also found between EPA + DHA and triacylglycerols in quartile 4. Our results indicate that increased consumption of fish as a source of n-3 fatty acids is beneficially associated with levels of HDL cholesterol and triacylglycerols.

Paper no. L9103 in *Lipids 38*, 359–365 (April 2003)

Cardiovascular diseases (CVD) are the leading cause of mortality and morbidity in Québec (Canada), and large interregional and ethnic differences exist in cardiovascular mortality rates and risk factors among the residents of Québec. The territory of Québec extends as far north as the 60th parallel and includes Cree communities of the James Bay region located between the 49th and 55th parallels, and Inuit communities of Nunavik, located north of the 55th parallel. Both of these Aboriginal populations historically have experienced much lower rates of ischemic heart disease (IHD) than the southern Québec population (mainly Caucasian). During the period 1992–1996, the age-standardized mortality rate (per 100,000 person-years) for IHD (CIM-9, 410–414) was 66.3 among Inuit, 92.8 for the Cree, and 140.2 for the Québec population as a whole (1). Epidemiologic data have demonstrated that n-3 polyunsaturated fatty acids (PUFA) may protect against heart disease (2–5). This protective effect is associated with a high intake of fish and marine products that are rich in n-3 fatty acids, eicosapentaenoic (EPA), and docosahexaenoic (DHA) acids. Studies reporting the beneficial effects of fish consumption have been conducted mainly among populations consuming large quantities of fish (6–8). Fish consumption is relatively low among Québecers, whereas among Aboriginal populations, consumption of traditional foods generally comprises a large amount of fish and marine products. However, in recent decades, changes in lifestyle and dietary patterns, including a decrease in the consumption of traditional foods, have been documented among James Bay Cree and, more recently, among Inuit of Nunavik (9–12). As observed in many Aboriginal populations, the abandonment of aspects of a traditional lifestyle and diet has been associated with increased prevalence of CVD and of their risk factors such as obesity, high blood pressure, and diabetes. In historical sequence, the Cree population has shown these Western shifts in lifestyle and diet for a longer period of time than Inuit in Nunavik. It can be hypothesized that the gradient in CVD mortality rates observed among Québecers, Cree, and Inuit is related to differences in lifestyle, with a special emphasis on diet. Our research team recently published detailed results of fatty acid profiles and the relations between n-3 fatty acids and CVD risk factors for each of these three populations (Québecers, Cree, and Inuit) (13–15). The goal of the present study was to group together and compare data collected among these three populations. The first specific objective was to compare fish intake and plasma phospholipid concentrations of EPA + DHA in the three populations. The second specific objective was to compare the relations between EPA + DHA and plasma HDL cholesterol and triacylglycerols.

SUBJECTS AND METHODS

Study design. Between 1990 and 1992, Santé Québec, an organization of the Québec Health and Social Services Ministry, conducted a series of health surveys among southern Québecers,

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Abbreviations: BMI, body mass index; CVD, cardiovascular disease; DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid; IHD, ischemic heart disease; PUFA, polyunsaturated fatty acids.

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James Bay Cree, and Inuit of Nunavik. The primary objective of these surveys was to collect information on physical, social, and psychosocial health with particular focus on "heart health" (16–19). This information was gathered in several stages, and all surveys followed a common standardized protocol. Face-to-face interviews were conducted at home by nurses using a questionnaire discussing lifestyle habits and sociodemographic characteristics. The same participants were invited to attend a clinical session that involved the collection of anthropometric and physiologic measurements such as blood pressure, and a blood specimen. Another face-to-face interview was conducted by a nutritionist or a nurse to collect information on dietary habits. For the present study, information on the demographic portrait and levels of CVD risk factors was obtained from the Santé Québec data files. Furthermore, from 1992 to 1996, our team used stored frozen plasma samples to determine plasma phospholipid fatty acid concentrations among these participants. Detailed results of these fatty acid analyses and their relations with CVD risk factors were published recently (13–15).

Study population. The target population of the Santé Québec health surveys comprised noninstitutionalized men and women between 18 and 74 yr of age. Three population samples were covered by the surveys, which aimed to collect information at the regional level with participants constituting a stratified probabilistic sample of each population. The statistical sampling design, developed by the Québec Bureau of Statistics, was described elsewhere (16). Our study population included 1460 Québecers, 917 James Bay Cree, and 426 Inuit of Nunavik, for whom concentrations of plasma phospholipid fatty acids were determined.

Plasma lipids, glucose, and insulin. Concentrations of plasma total cholesterol, triacylglycerols, LDL cholesterol, and HDL cholesterol were analyzed according to methods of the Lipid Research Clinics. Cholesterol and triacylglycerol concentrations were determined in plasma and in lipoprotein fractions using an Auto-Analyzer II (Technicon Instruments, Tarrytown, NY). The HDL fraction was obtained after precipitation of LDL in the infranatant with heparin and manganese chloride. Plasma glucose and insulin were measured according to methods described elsewhere (14,20).

Plasma phospholipid fatty acids. Plasma samples used for fatty acid analyses were stored at −80°C until time of analysis. All fatty acid analyses were conducted in the same laboratory at Guelph University, Canada. For the determination of the fatty acid composition in plasma phospholipids, 200-μL aliquots of plasma were extracted after the addition of chloroform/methanol (2:1, vol/vol), in the presence of a known amount of internal standard (diheptadecanoyl phospholipid) (21). The total phospholipid was isolated from the lipid extract by thin-layer chromatography using heptane/isopropyl ether/acetic acid (60:40:3, by vol) as the developing solvent. After transmethylation, using BF_3/methanol, the fatty acid profile was determined by capillary gas–liquid chromatography. Concentrations of fatty acids were expressed as percentages of phospholipid fatty acids.

Blood pressure. Using a standardized technique (22), trained survey nurses recorded two blood pressure measurements during the home visit and two additional readings at the clinical visit. The blood pressure values reported in this paper are based on the mean of the four measurements.

Lifestyle assessment and anthropometry. The trained survey nurses administered a standard questionnaire covering lifestyle habits (including, e.g., sociodemographic characteristics, alcohol intake, smoking status). Anthropometric measurements were recorded during the clinical visit. Height, waist, and hip girth measurements were recorded to the nearest centimeter, and weight to the nearest 100 g. In this study, body mass index (BMI) and waist girth were considered to measure obesity and abdominal fat accumulation (23).

Dietary assessment. Fish intake data were obtained using a 24-h dietary recall administered by nurses and nutritionists during the face-to-face interviews conducted in participants' homes (24–26). Fish intake comprised intake of fish, shellfish, and marine mammals. Models of standardized portions were used to define and describe amounts of food eaten by the participants.

Data analysis. Statistics presented in this paper were obtained from weighted data. Each respondent was given a value (weight) corresponding to the number of subjects he or she represented in his/her respective population (16). Thus, all results presented were weighted and representative of each of the three populations. Raw *n* values are presented for information only.

Means adjusted for sex and age and standard errors (SEM) were used to present characteristics of the three populations, and ANOVA was performed to compare means. Logistic regression was used to compare the prevalence of CVD risk factors adjusted for sex and age. The association between plasma phospholipid concentrations of EPA + DHA and HDL cholesterol and triacylglycerols was assessed by multiple linear regression analysis. The regression analyses were conducted on subjects free of prescribed drugs for CVD problems such as hypercholesterolemia, high blood pressure, diabetes, and heart disease. Adjustments were made for potential confounding effects of age, sex, BMI, waist girth, smoking, and alcohol intake. The potentially modifying effect of participants' population of origin on the relation between n-3 fatty acids and CVD risk factors was verified by using an interaction term. The three populations were grouped together and the association between concentrations of EPA + DHA was stratified into quartiles; HDL cholesterol and triacylglycerols were also assessed by multiple linear regression analysis. All statistical analyses were performed with the SAS software package (SAS Institute, Cary, NC) (27), and statistical significance was set at $P \leq 0.05$.

RESULTS

The study population was comprised of 2803 subjects between 18 and 74 yr of age (1323 men and 1480 women) (Table 1). The composition of the study population with respect to ethnicity was as follows: 52% Québecers (n = 1460, mean age = 40.1 yr), 33% Cree (n = 917, mean age = 35.2 yr), and 15% Inuit (n = 426, mean age = 38.2 yr). Characteristics of

TABLE 1
Sample Size of Study Population According to Ethnicity, Sex, and Age

Ethnic group	Men				Women				Total	(%)
Age (yr)	18–34	35–49	50–74	Total	18–34	35–49	50–74	Total		
n	711	278	334	1323	811	334	335	1480	2803	
Québecers	387	120	215	722	397	151	190	738	1460	(52)
James Bay Cree	243	103	76	422	293	117	85	495	917	(33)
Inuit of Nunavik	81	55	43	179	121	66	60	247	426	(15)

the three populations are presented in Table 2. Mean age- and sex-adjusted concentrations of total and LDL cholesterol were highest in Québecers, second-highest in Inuit, and lowest in Cree. Inuit had the highest concentrations of HDL cholesterol and the lowest ratio of total to HDL cholesterol compared with Cree and Québecers. Triacylglycerol concentrations were highest among Québecers, intermediate among Cree, and lowest among Inuit. Significant differences in mean systolic and diastolic blood pressures were found between Inuit and other populations, with Inuit having the lowest mean blood pressures. There were no differences among the three populations with respect to mean concentrations of plasma glucose. In contrast, higher concentrations of insulin were observed among Cree, followed by Québecers and Inuit, respectively. In particular, Cree women had elevated insulin concentrations (mean = 124 pmol/L, data not shown). Waist girth and BMI were highest among Cree, intermediate among Inuit, and lowest among Québecers. There was a large and statistically significant difference between Inuit and Québecers for the prevalence of cigarette smoking, i.e., Inuit smoked twice as much as Québecers (65 vs. 29%), with the prevalence of smoking among Cree intermediate between the two other groups. Québecers had the greatest proportion of occasional and habitual drinkers, followed by Inuit, whereas Cree had the greatest proportion of nondrinkers (including ex-drinkers). Many more Québecers used medication for CVD problems than Inuit and Cree participants.

Data from the 24-h dietary recalls revealed that on the day before each survey, the mean fish intake was 13 g [95% confidence interval (CI): 12.7–14.4] for Québecers, 60 g (95% CI: 47.5–71.9) for Cree, and 131 g (95% CI: 110.8–152.1) for Inuit (Fig. 1). Fish intake varied significantly among the three populations and increased with age in all populations. Plasma phospholipid concentration of EPA + DHA was highest among Inuit (8.0%, 95% CI: 7.5–8.4), second-highest among Cree (3.9%, 95% CI: 3.8–4.0), and lowest among Québecers (1.8%, 95% CI: 1.7–1.8). Concentrations of EPA + DHA increased significantly with age, and this increase was more pronounced among Cree and Inuit (Fig. 2).

For the next analyses, 399 subjects were excluded because they used medication for CVD problems. For the remaining

TABLE 2
Characteristics of Québecers, James Bay Cree, and Inuit of Nunavik Who Participated in the Santé Québec Health Surveys[a,b,c]

Characteristic	Québecers (n = 1460) Mean	(SEM)	Cree (n = 917) Mean	(SEM)	Inuit (n = 426) Mean	(SEM)	*P*-value
Total cholesterol (mmol/L)	5.3	(0.02)	5.0	(0.03)	5.3	(0.05)	<0.0001
LDL (mmol/L)	3.3	(0.02)	3.1	(0.03)	3.2	(0.04)	<0.0001
HDL (mmol/L)	1.3	(0.01)	1.3	(0.01)	1.5	(0.02)	<0.0001
Total/HDL cholesterol	4.3	(0.03)	4.2	(0.04)	3.8	(0.06)	<0.0001
Triglycerides (mmol/L)	1.6	(0.02)	1.4	(0.03)	1.2	(0.04)	<0.0001
Systolic blood pressure (mm Hg)	122.6	(0.36)	124.9	(0.47)	116.4	(0.67)	<0.0001
Diastolic blood pressure (mm Hg)	76.1	(0.23)	77.2	(0.30)	75.5	(0.43)	0.001
Glucose (mmol/L)	5.3	(0.04)	5.4	(0.05)	5.4	(0.07)	0.21
Insulin (pmol/L)	79.3	(1.71)	109.5	(2.35)	61.4	(3.32)	<0.0001
Waist girth (cm)	83.7	(0.32)	101.4	(0.42)	88.0	(0.62)	<0.0001
Body mass index (kg/m^2)	25.0	(0.13)	30.9	(0.16)	27.3	(0.24)	<0.0001
			Prevalence (%)				
Smoking status							
Smoker	29.1		36.0		64.7		<0.0001
Nonsmoker	70.9		64.0		35.3		
Alcohol intake							
None	11.7		69.7		52.3		<0.0001
Occasional or regular drinkers	88.3		30.0		47.7		
CVD medication							
Yes	22.9		12.0		5.1		<0.0001
No	77.1		88.0		94.9		

[a]Mean adjusted for sex and age (SEM); *P*-value obtained from ANOVA.
[b]Prevalence adjusted for sex and age (%); *P*-value obtained from logistic regression.
[c]Abbreviation: CVD, cardiovascular disease.

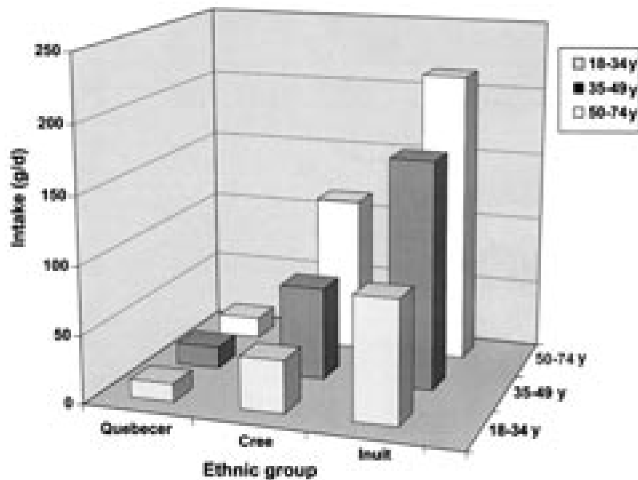

FIG. 1. Mean intake of fish and marine products by age group among Québecers, James Bay Cree, and Inuit of Nunavik.

subjects ($n = 2404$), the association between concentrations of EPA + DHA and HDL cholesterol and triacylglycerols was examined. Globally, the relationship between EPA + DHA and HDL cholesterol and triacylglycerols varied significantly according to population group ($P < 0.0001$ for HDL cholesterol and triacylglycerols). However, when stratifying EPA + DHA into quartiles, there was no modifying effect of population group on the relation between EPA + DHA and HDL cholesterol and triacylglycerols, ($P > 0.09$ for HDL and $P > 0.43$ for triacylglycerols). We found that HDL cholesterol increased with the increase in EPA + DHA, and the relation was significant in quartile 4 (Table 3). In contrast, triacylglycerol concentrations were inversely associated with EPA + DHA in quartile 4.

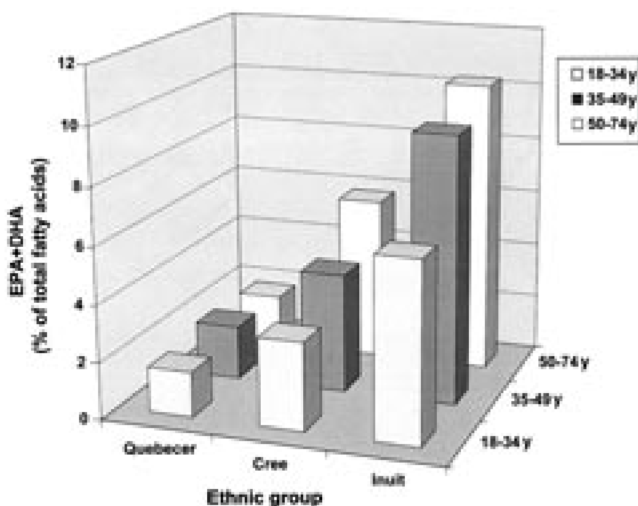

FIG. 2. Mean plasma phospholipid concentrations of eicosapentaenoic acid (EPA) + docosahexaenoic acid (DHA) by age group among Québecers, James Bay Cree, and Inuit of Nunavik.

TABLE 3
Regression Coefficients[a] (β values) of EPA + DHA in Relation to HDL Cholesterol and Triacylglycerols as Dependent Variables

	HDL		Triacylglycerols	
Quartiles of EPA + DHA	β coefficient	(*P*)	β coefficient	(*P*)
Quartile 1 (≤1.62)	0.088	(0.59)	1.060	(0.002)
Quartile 2 (1.62–2.35)	0.017	(0.95)	−0.178	(0.81)
Quartile 3 (2.36–4.03)	0.284	(0.22)	−0.962	(0.09)
Quartile 4 (≥4.04)	0.601	(<0.001)	−0.817	(<0.001)

[a]Regression coefficients and *P*-values obtained from multiple linear regression analysis; one model for each cardiovascular disease risk factor; each model included age, sex, body mass index, waist girth, smoking, and alcohol intake. Abbreviations: DHA, docosahexaenoic acid; EPA, eicosapentaenoic acid.

DISCUSSION

Our results show large cross-ethnic differences in plasma phospholipid concentrations of n-3 fatty acids among Québecers, James Bay Cree, and Inuit of Nunavik. We expected to observe such great differences among the three populations because their respective fish and marine product consumptions differed markedly. Fish and marine products are captured and consumed in large quantities all year around by Cree and Inuit, whereas Québecers generally consume small quantities of fish. This may reflect a south–north gradient in nutritional habits; Québecers have greater access to processed and market foods and are not necessarily as traditionally and culturally tied to fish consumption as these two Aboriginal groups in the province. Moreover, Québecers generally consume commercial fish such as cod, plaice, and haddock (28), which are lean-flesh fishes with low concentrations of EPA and DHA (Blanchet, C., and Dewailly, É., unpublished data). Québecers also consume fish from aquaculture operations such as salmon and trout for which the n-3 fatty acid concentrations may greatly vary depending on their feeding patterns (29–31). In fact, the plasma phospholipid level of n-3 fatty acids observed among Québecers closely approached that of U.S. citizens (29,30). In contrast, concentrations of n-3 fatty acids of Nunavik Inuit are probably among the highest reported to date, as are those of their counterparts throughout the circumpolar north (32–35). Traditional food consumption, obtained by hunting, fishing, trapping, and gathering activities, is still very common among Inuit populations, and because they reside in predominantly coastal locations, they have great access to marine resources. Inuit consume high quantities of fish and marine mammals, which are made up primarily of fatty-flesh and n-3 fatty acid-rich species (12).

James Bay Cree had fish intake and plasma phospholipid concentrations of n-3 fatty acids intermediate between the two other populations. Cree are not traditionally marine resource harvesters, consuming more freshwater fish and terrestrial mammals; for a number of reasons, they have demonstrated these shifts in consumption to a more Westernized diet for a longer period of time than the Inuit population of Nunavik (15,26,36,37). However, the level of n-3 fatty acids observed among James Bay Cree is certainly much higher

than that of the majority of Westernized populations. Furthermore, in a recent study, we examined the profile of n-3 fatty acids according to geographical place of residence of James Bay Cree (15). Results showed that fish intake and concentrations of EPA + DHA were significantly higher among coastal residents (3.8%; 95% CI: 3.7–3.9) than those in inland communities (3.2%; 95% CI: 3.0–3.3), which likely reflected the greater accessibility and availability of fish in coastal areas.

The relation between fish intake and plasma phospholipid concentrations of n-3 fatty acids could not be examined directly in this study because fish intake data were obtained from a single 24-h dietary recall, which is not representative of regular long-term consumption habits (38). Nevertheless, our results showed that fish intake varied significantly among these three populations, with figures for fish intake among Inuit being approximately two and ten times greater than that of Cree and Québecers, respectively. Consequently, we observed that the population level of fish and marine product consumption was reflected in plasma concentrations of EPA and DHA. In the three populations, fish intake and plasma concentrations of EPA and DHA increased significantly with age; this association was stronger among Cree and Inuit. These observations are consistent with other dietary surveys conducted among northern Aboriginal populations, which have indicated positive correlations between age and traditional food consumption (12,33,34,39–41). Older Aboriginal people consume fish, marine products, and wild animals more frequently than younger adults and youth. The greater availability of market foods in many Aboriginal regions appears to be attracting young people more quickly than older individuals.

A number of factors such as high blood pressure, elevated plasma lipids and lipoproteins, diabetes, obesity, and diets high in saturated and *trans*-fatty acids increase the risk of CVD (42–46). In this study, we observed significant differences in CVD risk factor levels among the three populations. For HDL cholesterol, the ratio of total to HDL cholesterol, triacylglycerols, systolic and diastolic blood pressures, and insulin, Inuit, despite the high prevalence of cigarette smoking and obesity, had the lowest risk status for CVD compared with Cree and Québecers. Moreover, it is well known that the Inuit population is younger than that of Cree or south Québecers and that CVD risk increases with age. The adjustment for age of CVD risk factor levels did not change the lower CVD risk level observed among the Inuit population compared with Cree and Quebec populations. High triacylglycerol and low HDL cholesterol concentrations are now well recognized as key risk factors for CVD (43,46). A number of intervention studies have demonstrated the triacylglycerol-lowering effect of n-3 fatty acids (47–52). Some studies have also observed an HDL-increasing effect of n-3 fatty acids (49,53,54). Surveys conducted in animals and humans suggest that the suppression of the hepatic VLDL and triacylglycerol production is the primary mechanism by which n-3 fatty acids reduce triacylglycerol levels (43). This effect is mediated by increased fatty acid oxidation and a decrease in fatty acid synthesis, which in turn decreases fatty acid availability for triacylglycerol synthesis (43,53). The mechanism by which n-3 fatty acids increase HDL may be related to the decrease in lipid transfer protein activity, favoring an increase in larger HDL (HDL_2 particles), which are considered to be the most antiatherogenic HDL subtype (53–55).

Detailed statistical analyses published previously by our team revealed that positive association between n-3 fatty acids and HDL concentrations was consistent among Inuit and Cree populations (13–15). Among Québecers, only EPA and the ratio of EPA to arachidonic acid were positively associated with HDL cholesterol (13). Moreover, no consistent and inverse association between n-3 fatty acids and triacylglycerols was found among Québecers, whereas inverse relations were observed among Cree and Inuit. It seems likely that the levels of fish intake or n-3 fatty acid concentrations among Québecers were not high enough to show a significant and potential beneficial effect of n-3 fatty acids on plasma triacylglycerols, whereas the strength of the inverse association observed among Cree and Inuit likely reflected their higher fish and marine product consumption. Moreover, statistical analyses performed in the present study in using quartiles of EPA + DHA suggested a threshold value in plasma phospholipids (quartile 4) at which a potential beneficial effect of EPA + DHA on HDL and triacylglycerols could be observed. In fact, only 0.4% of Québecers had plasma phospholipid concentrations of EPA + DHA included in quartile 4, whereas 89% had concentrations lower than the median (quartiles 1 and 2). In contrast, the higher EPA + DHA concentrations of James Bay Cree and Inuit allowed the inclusion of 31% of the Cree and 84% of the Inuit in quartile 4.

In the present study, we cannot estimate the daily intake of EPA + DHA associated with a plasma EPA + DHA concentration in quartile 4. However, it was reported that a consumption of a minimum of 1 g/d of n-3 fatty acids can be expected to significantly lower triacylglycerols (43). Our results agree with these findings, i.e., a minimum intake or concentration of n-3 fatty acids is required to obtain an effect on triacylglycerols or HDL cholesterol. The daily fish intake of the Québecer, Cree, and Inuit populations provided ~170, 700–900, and 2115 mg of EPA + DHA, respectively. Recently, an American group of nutrition scientists recommended a combined average EPA + DHA intake of 650 mg for optimal health and CVD prevention (56). Numerous studies have indicated that long-term consumption of fish (up to 2–3 servings/wk) is associated with lower primary and secondary heart attack rates and death from CVD (3,4,47,57–61). Although our study design differed from that of those prospective studies, data on CHD mortality rates among the three study populations suggest that the traditional diets of Cree and Inuit, which are rich in n-3 fatty acids, contribute to their relatively favorable IHD mortality rate. However, as the Cree and Inuit lifestyle and diet become increasingly Westernized, their relatively low level of risk for IHD may be lost. Hence, the promotion of a healthy nutritional diet among these populations should include nutritious market foods and traditional foods of marine

origin, in particular among young Arboriginal people, who are less likely to eat traditional foods than their parents. Québecers must also be encouraged to increase their consumption of fish and marine products, especially species rich in n-3 fatty acids.

ACKNOWLEDGMENTS

The fatty acid analyses were supported by the Medical Research Council of Canada and by the Department of Indian Affairs of Canada. We are grateful to Santé Québec for providing the data bases and blood samples of subjects from Southern Québec, Inuit of Nunavik, and James Bay Cree who participated in the surveys conducted in their respective regions. Also, we wish to thank Christopher Furgal for reviewing this manuscript.

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[Received July 1, 2002; accepted January 2, 2003]