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0	true zero or a value rounded to zero
0^s	value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded
^{p}	preliminary
^{r}	revised
x	suppressed to meet the confidentiality requirements of the *Statistics Act*
^{E}	use with caution
F	too unreliable to be published
*	significantly different from reference category ($p < 0.05$)

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Abstract

Background: Cardioprotective properties have been associated with two fatty acids—eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). The Omega-3 Index indicates the percentage of EPA + DHA in red blood cell fatty acids. Omega-3 Index levels of the Canadian population have not been directly measured.

Data and methods: Data for respondents aged 20 to 79 from cycle 3 (2012/2013) of the Canadian Health Measures Survey were used to calculate means and the prevalence of Omega-3 Index coronary heart disease (CHD) risk cut-offs—high (4% or less), moderate (more than 4% to less than 8%), and low (8% or more)—by sociodemographic and lifestyle characteristics, including fish consumption and use of omega-3 supplements. Associations between the Omega-3 Index and CHD-related factors including biomarkers, risk factors, and previous CHD events, were examined in multivariate regression models.

Results: The mean Omega-3 Index level of Canadians aged 20 to 79 was 4.5%. Levels were higher for women, older adults, Asians and other non-white Canadians, omega-3 supplement users, and fish consumers; levels were lower for smokers and people who were obese. Fewer than 3% of adults had levels associated with low CHD risk; 43% had levels associated with high risk. No CHD-related factor was associated with the Omega-3 Index when control variables were taken into account.

Interpretation: Omega-3 Index levels among Canadian adults were strongly related to age, race, supplement use, fish consumption, smoking status and obesity. Fewer than 3% of adults had Omega-3 Index levels associated with low risk for CHD.

Key words: Coronary heart disease, DHA, EPA, fish consumption, RBC fatty acid composition

The fatty acid composition of red blood cells (RBC) is an indicator of health and nutritional status. Two fatty acids—eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA)—have been associated with cardioprotective effects.[1-4] Incorporation of EPA and DHA into red blood cell membranes changes the properties of the cell. Such changes include improving blood flow, reducing inflammation, and lowering blood triglyceride levels.[3]

Epidemiological and clinical studies have reported that blood levels of EPA and DHA are correlated with the incidence of cardiovascular events.[1,5-8] Higher EPA+DHA levels have been associated with protective coronary heart disease (CHD) biomarkers including higher high-density lipoprotein cholesterol levels and lower triglyceride levels.[9,10] Lower EPA+DHA levels have been associated with cardiovascular risk factors, including body mass index (BMI) and smoking.[10-12]

The Omega-3 Index is the combined percentage of EPA and DHA of total fatty acids in red blood cell membranes. In 2004, the Index was proposed by Harris and von Schacky as a biomarker for risk of death from CHD.[13,14] Based on a synthesis of evidence from primary and secondary prevention studies in conjunction with their own clinical and laboratory experiments, they suggested cut-points of 4% or less, more than 4% to less than 8%, and 8% or more to define high-, moderate- and low-risk categories, respectively, for CHD.[13] Between the high- and low-risk categories, the risk for cardiac events is reduced by up to 90%.[13] An Omega-3 Index of 8% is achievable through daily intake of 500 mg EPA+DHA or through weekly consumption of at least two servings of fatty fish.[11,13,15,16]

The purpose of this study was to estimate EPA + DHA levels in terms of the Omega-3 Index and the cut-points for CHD risk among a nationally representative sample of Canadian adults. Factors related to Omega-3 Index levels and potential associations with CHD-related factors were examined, using direct measures of RBC fatty acids from the 2012/2013 Canadian Health Measures Survey (CHMS).

Data and methods

The CHMS is an ongoing survey conducted by Statistics Canada in partnership with Health Canada and the Public Health Agency of Canada.[17-20] Cycle 3, which took place from January 2012 through December 2013, collected information from respondents aged 3 to 79 living in households in 16 locations across Canada. Approximately 96% of Canadians were represented. The survey excluded full-time members of the Canadian Forces and residents of the three territories, reserves and other Aboriginal settlements, institutions, and certain remote regions.

The CHMS involves an at-home interview to gather socioeconomic, health, and lifestyle information, and a visit to a mobile examination centre (MEC) for a series of direct physical measurements, including blood collection by a certified phlebotomist.

Of the households selected for the CHMS, 74.1% agreed to provide information on household composition, 88.4% of which responded to the household questionnaire. A total of 5,785 respondents (78.8% of those who responded to the household questionnaire) reported to the MEC. A random sample of those aged 20 to 79 was chosen to have their blood analyzed for RBC fatty acids. Of the 3,184 eligible MEC participants, 2,042 were selected, 1,984 of whom had valid laboratory results. The combined response rate for the RBC fatty acids subsample was 49.2%.[17]

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This analysis focuses on the 1,984 respondents aged 20 to 79 with valid fatty acid measures.

RBC fatty acid analysis

For RBC fatty acid profiling, approximately 2mL of blood was collected in EDTA tubes. The samples were refrigerated and shipped in ice to Health Canada in Ottawa, where RBCs were isolated and analyzed for the fatty acid profile by gas chromatography.[21] Mean selected fatty acid levels, expressed as weight % of total identified fatty acids, are presented in Appendix Table A.

Covariates

Omega-3 Index levels were examined by sex, age group, racial background, household income, education, smoking status, and obesity. Supplement use and fish consumption, the most important sources of EPA and DHA, were also examined.

Three age groups were specified: 20 to 39, 40 to 59, and 60 to 79.

Based on an extensive list, respondents identified their racial background. Those who indicated "white" were classified as such; those who indicated "Korean," "Filipino," "Japanese," "Chinese," "South Asian," or "Southeast Asian" were grouped as "Asian," as these cultures tend to eat more fish. All other backgrounds, including "Aboriginal," were classified as "Other."

Based on the median reported for the CHMS sample ($60,000 to $69,999), household income was classified into two categories: less than $70,000 and $70,000 or more.

Education was dichotomized as college diploma/university degree versus less than college diploma/university degree. For 20- to 24-year-olds, who might still be enrolled in an educational institution, highest level of education in the household was identified.

Smoking status was grouped into two categories: daily or occasional smokers versus non-smokers (former and never-smokers).

Body mass index (BMI) was based on measured height and weight and calculated by dividing height in kilograms by the square of height in metres (kg/m^2). Respondents with a BMI of 30 or more were defined as obese.

Supplement use

At both the household and MEC interviews, respondents were asked about medications they had taken in the past month. If possible, respondents provided a drug identification number (DIN)/natural health product number (NPN) for each medication, and reported the last time they had taken it: today, yesterday, within the last week, within the last month, and more than one month ago.

To identify supplements containing omega-3s, Health Canada's Drug Product Database (DPD) and Licensed Natural Health Product Database (LNHPD) were consulted on February 12, 2015. From the DPD, ingredients containing "docosahexaenoic acid," "eicosapentaenoic acid," "fish oil," "cod liver oil," or "fatty acids" were retained. From the LNHPD, proper names, common names, potency constituents and source materials containing any derivative of the terms "DHA," "docosahexaenoic acid," "EPA," "eicosapentaenoic acid," "omega-3," "fish oil," "cod liver oil," or "krill oil" were retained. These DINs/NPNs were merged with those reported to the CHMS, and all omega-3 supplements were flagged. For this analysis, supplement users were defined as respondents who had taken an omega-3-containing supplement within one month of the MEC visit.

Fish consumption

All fish contain EPA and DHA, but levels vary by species and environment.[1,22] At the MEC, respondents were asked how often in the past month they had consumed any of 27 fish/shellfish provided in a list that included some of the more oily/fatty fish, which contain the most EPA+DHA—for example, mackerel, salmon, white (albacore) tuna, herring, and sardines.

For each respondent, fish from the list were summed. Three consumption variables were defined: 1) a serving of any of the 27 fish/shellfish at least twice a week versus less; 2) a weekly serving of at least one oily/fatty fish versus less; and 3) at least two weekly servings of fish, at least one of which is oily/fatty, versus less.

Coronary Heart Disease (CHD) variables

This analysis examined relationships between Omega-3 Index levels and CHD-related factors—CHD biomarkers, risk factors and previous CHD events. As part of blood collection, high-density lipoprotein cholesterol (HDL-C) and total cholesterol (TC) were measured in serum; triglycerides and low-density lipoprotein cholesterol (LDL-C) were taken from a fasting subsample of participants. These CHD biomarkers were modeled as continuous and dichotomous variables based on thresholds for "healthy" and "unhealthy" (Text table 1).

Respondents were considered to have high blood pressure if they met any of the following criteria: measured systolic blood pressure of 140 or more mmHg and/or diastolic blood pressure of 90 or more mmHg; use of any antihypertensive medications defined by Anatomical Therapeutic Chemical (ATC) codes[23] or self-reported use of blood-pressure-lowering medication(s); or a self-report of having been diagnosed with high blood pressure by a health care provider.

Respondents who reported having been diagnosed with heart disease by a health care provider were classified as such; ever having a heart attack was also reported.

Text table 1
Thresholds for coronary heart disease (CHD) biomarkers[24-26]

CHD biomarker	Healthy level	Unhealthy level
Triglyceride levels	Less than 1.7 mmol/L	1.7 mmol/L or more
LDL cholesterol (LDL-C)	Less than 3.5 mmol/L	3.5 mmol/L or more
HDL cholesterol (HDL-C), by sex		
Men	1.0 mmol/L or more	Less than 1.0 mmol/L
Women	1.3 mmol/L or more	Less than 1.3 mmol/L
Ratio of total cholesterol to HDL (TC:HDL)	5.0 mmol/mmol or less	More than 5.0 mmol/mmol

Analysis

Descriptive statistics were used to estimate the mean of the Omega-3 Index, expressed as weight % of total identified fatty acids. The population prevalence of low-risk (8% or more), intermediate-risk (more than 4% to less than 8%) and high-risk (4% or less) Omega-3 Index categories was examined. Means and prevalence were estimated by socio-demographic and lifestyle characteristics. Associations between CHD-related factors and the Omega-3 Index were examined in multivariate regression models.

All analyses were conducted in SAS 9.3 and SUDAAN v.11.0.1 using DDF=11 in the procedure statements to account for the limited degrees of freedom in the CHMS. Because the RBC fatty acid information was collected on a subsample of CHMS respondents, special weights were applied to represent the population aged 20 to 79. To account for the complex sampling design, bootstrap weights provided with the data were used for variance estimation (95% confidence intervals) and significance testing. Significance was defined as $p < 0.05$.

Results

Study sample

The sample was equally divided between men and women (Table 1). Most respondents (77%) were white. Three-quarters were non-smokers, and one-quarter were obese. An estimated 11% reported taking an omega-3-containing supplement in the previous four weeks. A third (35%) consumed fish at least twice a week; 15% consumed fish at least twice a week, one or more of which was a fatty/oily fish.

Table 1
Characteristics of study population, household population aged 20 to 79, Canada excluding territories, 2012/2013

Characteristics	%	95% confidence interval from	to
Sex			
Men	49.6	49.6	49.6
Women	50.4	50.4	50.4
Age group			
20 to 39	37.3	37.3	37.3
40 to 59	39.7	39.7	39.7
60 to 79	23.0	23.0	23.0
Race			
White	76.7	62.8	86.5
Asian†	13.7[E]	7.2	24.4
Other	9.6[E]	5.8	15.4
Highest household income			
Less than $70,000	50.2	42.6	57.7
$70,000 or more	49.8	42.3	57.4
Education			
Less than college diploma/university degree	33.8	27.1	41.3
College diploma/University degree	66.2	58.7	72.9
Supplement use			
No	89.3	85.3	92.4
Yes	10.7	7.6	14.7
Fish consumption			
Less than twice a week	62.9	55.4	69.9
At least twice a week	37.1	30.1	44.6
Less than one serving of oily fish a week	72.7	64.5	79.6
At least one serving of oily fish a week	27.3	20.4	35.5
Less than twice a week (one serving oily)	84.6	77.9	89.5
At least twice a week (one serving oily)	15.4[E]	10.5	22.1
Smoking status			
Daily or occasional	23.2	18.3	28.9
Non-smoker	76.8	71.1	81.7
Obesity			
No	72.2	67.3	76.7
Yes	27.8	23.3	32.7

[E] use with caution
† Korean, Filipino, Japanese, Chinese, South Asian, Southeast Asian
Source: 2012/2013 Canadian Health Measures Survey.

Levels vary by age and race

In 2012/2013, the mean Omega-3 Index level of 20- to 79-year-olds was 4.5% (Table 2). Levels were significantly lower among men than women, and among younger and middle-aged adults versus older adults. Significant differences were evident by race, with Asians and other non-white Canadians having higher levels than white Canadians. As expected, people who took an omega-3-containing supplement and those who consumed fish more frequently had significantly higher levels than those who did not use a supplement or consume fish. Daily/Occasional smokers and obese individuals had lower levels than non-smokers and those who were not obese. These patterns prevailed among men and women.

In a multivariate regression model, combined associations between Omega-3 Index levels and selected covariates were examined (Table 3). Inclusion of sex, age, race, supplement use, fish consumption, smoking status, and obesity in the model explained 42% of the variability in Omega-3 Index levels. Similar to the bivariate analyses, younger age, smoking, and obesity were negatively associated with the Omega-3 Index, while Asian and non-white race, supplement use and fish consumption showed positive associations. However, when the other factors were taken into account, sex was no longer associated with Omega-3 Index levels.

Coronary heart disease and RBC fatty acids

Overall, fewer than 3% of Canadians adults had Omega-3 Index levels associated with low risk for CHD (Table 4). The prevalence of levels associated

with low risk was 4% for women, 7% for individuals who had at least two servings of fish a week, and 10% for supplement users.

By contrast, 43% of adults had Omega-3 Index levels associated with high risk for CHD. The prevalence of high-risk levels was greater among men than women, younger and middle-aged adults compared with older adults, and obese individuals compared with those who were not obese. The prevalence of high-risk levels was relatively low among Asians, fish consumers and non-smokers.

Associations between CHD-related factors and Omega-3 Index levels were examined in two models: 1) unadjusted for covariates, and 2) adjusted for sex, age, race, supplement use, fish consumption, smoking status, and obesity (Table 5). Each CHD-related factor was introduced separately.

In the unadjusted models, a negative association emerged for triglycerides: as triglyceride levels increased, the Omega-3 Index decreased; the healthy/unhealthy threshold for triglycerides was not significant. For LDL-C, no significant dose-response relationship existed, but the healthy/unhealthy threshold for LDL-C was positively related to the

Table 2
Mean Omega-3 Index levels, by sex and selected characteristics, household population aged 20 to 79, Canada excluding territories, 2012/2013

	Total			Men			Women		
		95% confidence interval			95% confidence interval			95% confidence interval	
	Mean %	from	to	Mean %	from	to	Mean %	from	to
Total	4.5	4.2	4.8	4.3	4.1	4.6	4.7‡	4.3	5.0
Age group									
20 to 39	4.3*	4.0	4.6	4.2*	3.8	4.5	4.4*	3.8	4.9
40 to 59	4.4*	4.1	4.7	4.2*	3.8	4.6	4.6	4.3	5.0
60 to 79†	5.0	4.7	5.3	4.8	4.5	5.1	5.2	4.7	5.7
Race									
White†	4.3	4.1	4.5	4.2	3.9	4.4	4.4	4.1	4.7
Asian§	5.5*	4.6	6.4	5.1*	4.2	5.9	5.9*‡	5.0	6.7
Other	4.8*	4.3	5.4	4.8*	4.2	5.5	4.8	4.2	5.4
Household income									
Less than $70,000	4.4	4.2	4.6	4.3	4.1	4.6	4.5	4.2	4.7
$70,000 or more†	4.6	4.1	5.1	4.3	3.9	4.8	4.8‡	4.3	5.4
Education									
Less than college diploma/ university degree	4.3	4.0	4.6	4.2	3.8	4.7	4.3*	4.1	4.6
College diploma/ University degree†	4.6	4.3	4.9	4.4	4.1	4.7	4.8‡	4.4	5.3
Supplement use									
No†	4.3	4.1	4.6	4.2	3.9	4.4	4.5‡	4.2	4.7
Yes	6.0*	5.5	6.5	5.6*	5.3	5.9	6.5*‡	5.7	7.3
Fish consumption									
Less than twice a week†	4.3	4.1	4.6	4.3	4.0	4.6	4.3	4.1	4.6
At least twice a week	5.2*	4.7	5.8	5.0*	4.6	5.3	5.5*‡	4.7	6.2
Less than one serving of oily fish a week†	4.8	4.5	5.0	4.7	4.4	5.0	4.8	4.5	5.2
At least one serving of oily fish a week	5.7*	4.9	6.5	5.5*	5.1	5.9	6.0	4.8	7.1
Less than twice a week (one serving oily)†	4.5	4.2	4.7	4.4	4.1	4.7	4.5	4.3	4.8
At least twice a week (one serving oily)	5.8*	4.9	6.7	5.5*	5.0	5.9	6.1*	4.8	7.4
Smoking status									
Daily or occasional	3.7*	3.4	4.0	3.6*	3.3	4.0	3.7*	3.3	4.2
Non-smoker†	4.7	4.4	5.0	4.6	4.3	4.8	4.9‡	4.5	5.2
Obesity									
No†	4.6	4.2	5.0	4.4	4.1	4.8	4.8	4.3	5.2
Yes	4.2*	4.0	4.4	4.1	3.9	4.3	4.3	4.0	4.6

† reference category
* significantly different from reference category ($p < 0.05$)
‡ significantly different from men ($p < 0.05$)
§ Korean, Filipino, Japanese, Chinese, South Asian, Southeast Asian
Source: 2012/2013 Canadian Health Measures Survey.

Table 3
Regression model estimates (beta, p-values) of association between selected characteristics and Omega-3 Index levels, household population aged 20 to 79, Canada excluding territories, 2012/2013

	Control model	
Characteristic	**beta**	**p-value**
R^2	0.422	
Sex		
Men	-0.142	0.119
Women†	. . .	. . .
Age group		
20 to 39	-0.608	0.001
40 to 59	-0.497	0.011
60 to 79†	. . .	. . .
Race		
White†	. . .	. . .
Asian‡	1.576	0.001
Other	0.760	0.007
Supplement use		
No†	. . .	. . .
Yes	1.719	0.000
Fish consumption		
Less than twice a week†	. . .	. . .
At least twice a week	0.690	0.001
Smoking status		
Daily or occasional	-0.564	0.000
Non-smoker†	. . .	. . .
Obesity		
No†	. . .	. . .
Yes	-0.269	0.027

† reference category
‡ Korean, Filipino, Japanese, Chinese, South Asian, Southeast Asian
. . . not applicable
Source: 2012/2013 Canadian Health Measures Survey.

Omega-3 Index. Positive associations were also found for HDL-C and the TC:HDL. However, when the covariates were taken into account, these relationships were no longer significant.

As well, no relationships between the Omega-3 Index and high blood pressure, having a heart disease diagnosis or a previous heart attack were found in either the unadjusted or adjusted models.

Table 4
Prevalence of coronary heart disease (CHD) risk according to Omega-3 Index cut-offs, by selected characteristics, household population aged 20 to 79, Canada excluding territories, 2012/2013

	High CHD risk			Moderate CHD risk			Low CHD risk		
	4% or less			More than 4% to less than 8%			8% or more		
		95% confidence interval			95% confidence interval			95% confidence interval	
Characteristic	%	from	to	%	from	to	%	from	to
Total	42.7	35.4	50.4	54.6	47.7	61.3	2.6[E]	1.3	5.4
Sex									
Men	48.1*	38.8	57.5	50.7	41.6	59.8	F	...	...
Women†	37.5	30.3	45.3	58.5	51.7	64.9	4.1[E]	2.0	8.3
Age group									
20 to 39	50.1*	39.1	61.1	49.2*	38.3	60.2	F	...	...
40 to 59	45.4*	35.9	55.1	52.2*	42.5	61.7	F	...	...
60 to 79†	26.3	21.4	31.8	67.6	62.5	72.3	F	...	...
Race									
White†	47.6	41.4	54.0	50.9	44.9	56.9	1.5[E]	0.8	2.6
Asian‡	23.2*[E]	11.7	40.8	66.7*	54.5	77.0	F	...	...
Other	31.4[E]	15.3	53.7	67.0	46.0	82.9	F	...	...
Household income									
Less than $70,000	42.7	33.0	52.9	56.0	45.7	65.7	1.4*[E]	0.7	2.7
$70,000 or more†	42.8	30.1	56.6	53.3	41.2	65.0	F	...	...
Education									
Less than college diploma/ university degree	49.6	38.1	61.0	48.5	36.7	60.5	F	...	...
College diploma/ University degree†	39.0	30.1	48.6	58.0	49.2	66.3	F	...	...
Supplement use									
No†	47.0	39.0	55.0	51.2	43.6	58.8	F	...	...
Yes	F	...	...	83.2*	71.1	90.9	9.5*[E]	5.9	14.9
Fish consumption									
Less than twice a week†	45.4	36.5	54.6	53.5	44.6	62.2	F	...	...
At least twice a week	23.9*[E]	15.3	35.4	69.6*	61.1	77.0	6.5*[E]	3.1	13.1
Less than one serving of oily fish a week†	30.1	22.8	38.5	68.2	60.7	74.9	F	...	...
At least one serving of oily fish a week	14.4*[E]	7.7	25.3	75.2	62.7	84.5	F	...	...
Less than twice a week (one serving oily)†	41.7	33.9	50.1	56.7	48.8	64.3	1.5[E]	0.8	2.9
At least twice a week (one serving oily)	13.9*[E]	6.6	26.9	74.5*	61.4	84.3	F	...	...
Smoking status									
Daily or occasional	70.8*	56.5	81.9	28.3*[E]	17.3	42.9	F	...	...
Non-smoker†	34.3	27.9	41.4	62.5	56.8	67.9	3.2[E]	1.6	6.4
Obesity									
No†	39.3	30.3	49.1	57.3	48.6	65.5	F	...	...
Yes	51.7*	46.2	57.2	47.9*	42.5	53.2	F	...	...

† reference category
* significantly different from reference category ($p < 0.05$)
§ Korean, Filipino, Japanese, Chinese, South Asian, Southeast Asian
[E] use with caution
F too unreliable to be published
... not applicable
Source: 2012/2013 Canadian Health Measures Survey.

Discussion

This is the first study to analyze RBC fatty acids based on direct measures of a nationally representative sample of Canadian adults. An Omega-3 Index of 8% or more may minimize the risk of death from CHD, and people with an Index of 4% or less may be at greater risk.[13] According to CHMS results, 2.6% of Canadians aged 20 to 79 met the Omega-3 Index level associated with low risk of CHD, and 43% were in the high-risk category. The mean Omega-3 Index for the adult population was 4.5%.

Comparable Canadian studies are lacking. The mean Omega-3 Index found in this analysis is slightly below values reported by a pilot study of South Asian (6.6%) and white Canadians (5.9%) in the National Capital Region of Canada.[21] The prevalence of subjects with an Omega-3 Index of at least 8% in the pilot study was also higher (19.8% for South Asian Canadians and 9.4% for white Canadians) than the 2.6% prevalence reported here. The smaller sample size (649 versus 1,984) and restriction of the pilot study to one location (National Capital Region versus Canada-wide) and to two ethnic groups (South Asian and white) may be reasons for these differences.

However, the Omega-3 Index has been measured in many other populations.[27] For example, mean values for healthy subjects in Kansas City (4.9%)[11] and in the Framingham offspring cohort (5.6%)[12] are in line with the mean value for Canadian adults in this analysis. Considerably higher Omega-3 Index means have been found in other countries: 6.96% in Europe overall[27]; 7.15% in Germany[27]; 7.10% in Spain[28]; 6.08% in Norway[29]; 11.81% in Korea[30]; and 9.58% in Japan.[27]

Comparable Omega-3 Index levels among Canadians and Americans may reflect similarities in diet, heredity, and socioeconomic conditions. Reasons for the higher values in European and Asian countries are not known, but may reflect greater consumption to greater consumption of fish, although heredity may also play a role.

Neither a recent meal, even if rich in EPA+DHA, nor cardiac events influence the Omega-3 Index. Possibly because of the long half-life (100 to 120 days) of RBC, long-term dietary intake and heredity have been identified as main predictors of the Omega-3 Index: long-term intake explains 15% to 25% of its variability, and heredity accounts for 24%.[12] This is consistent with results from the present study: race, supplement use and fish consumption were strongly related to the Omega-3 Index among Canadian adults.

A number of other factors also appeared to be influential. Similar to previous research,[7,11,12] older Canadians had higher Omega-3 Index levels, and smokers and obese individuals had lower levels. Smoking and obesity suggest an unhealthy lifestyle, which, in turn, may be related to a diet lacking in Omega-3s. In this study, fish consumption was similar between smokers and non-smokers, but smokers were significantly less likely to take an omega-3-containing supplement. Income was not associated with the Omega-3 Index, although education was among women.

CHD biomarkers were significantly associated with the Omega-3 Index in the unadjusted models, but when the control factors were taken into account, these relationships disappeared. Results of other studies have been inconclusive. Among Quebec adults, EPA+DHA levels were positively associated with LDL-C and TC:HDL, and negatively associated with HDL-C,[31] even in adjusted models. Another Quebec study found that when age and sex were taken into account, DHA levels, but not EPA levels, were negatively associated with triglycerides, and plasma n-3 fatty acids were positively associated with HDL-C.[9]

The lack of a significant relationship between triglycerides and Omega-3 Index levels is contrary to other research.[7,12] Significant lowering of triglycerides requires consistent intake of large doses of EPA+DHA.[32] A review found that triglyceride concentrations decreased by 25% among subjects who had taken a fish oil supplement of approximately 4 g per day.[33] It has been suggested that the relationship between omega-3 fatty acid biomarkers and triglycerides is causal, because omega-3 fatty acids lower triglyceride secretion in the liver.[34] The small CHMS sample limits the power of statistical testing; it is likely that the marginal finding ($p = 0.05$) would benefit from a larger sample.

No relationship emerged between the Omega-3 Index and high blood pressure,

Table 5
Unadjusted and adjusted regression model estimates (betas, p-values) of association between coronary-heart-disease-related factors and Omega-3 Index levels, household population aged 20 to 79, Canada excluding territories, 2012/2013

	Unadjusted		Adjusted‡	
Coronary-heart-disease-related factors	beta	p-value	beta	p-value
Triglyceride level				
Healthy (less than 1.7 mmol/L)†	. . .	. . .	. . .	. . .
Unhealthy (1.7 mmol/L or more)	-0.274	0.087	-0.268	0.145
Continuous	-0.311	0.006	-0.235	0.050
LDL cholesterol level				
Healthy (less than 3.5mmol/L)†	. . .	. . .	. . .	. . .
Unhealthy (3.5 mmol/L or more)	0.501	0.020	0.244	0.163
Continuous	0.107	0.301	0.072	0.447
HDL cholesterol level				
Healthy (more than 1.0 mmol/L for men; more than 1.3 mmol/L for women)†	. . .	. . .	. . .	. . .
Unhealthy (1.0 mmol/L or less for men; 1.3 mmol/L or less for women)	-0.272	0.042	-0.182	0.314
Continuous	0.384	0.012	0.010	0.958
Ratio of total cholesterol to HDL cholesterol				
Healthy (less than 5.0 mmol/mmol)†	. . .	. . .	. . .	. . .
Unhealthy (5.0 mmol/mmol or more)	-0.398	0.051	-0.153	0.306
Continuous	-0.138	0.045	-0.025	0.584
High blood pressure				
No†	. . .	. . .	. . .	. . .
Yes	0.234	0.093	-0.015	0.925
Heart disease diagnosis				
No†	. . .	. . .	. . .	. . .
Yes	0.275	0.163	0.129	0.531
Ever had heart attack				
No†	. . .	. . .	. . .	. . .
Yes	0.355	0.287	0.190	0.558

† reference category
‡ adjusted for sex, age group, race, supplement use, fish consumption, smoking status, and obesity
. . . not applicable
Note: Each coronary-disease-related factor was examined separately; no two factors were entered at once.
Source: 2012/2013 Canadian Health Measures Survey.

What is already known on this subject?

- Eicosapentaenoic acid (EPA) and Docosahexaenoic acid (DHA) are associated with cardioprotective effects.
- The Omega-3 Index (the sum of EPA+DHA in red blood cells) can be used to estimate the percentage of Canadians at higher risk for coronary heart disease (CHD).

What does this study add?

- Cycle 3 of the Canadian Health Measures Survey provides, for the first time, direct (blood) measures of the Omega-3 Index on a national sample of Canadians.
- Omega-3 Index levels vary with sex, age, race, supplement use, fish consumption, smoking status, and obesity.
- Fewer than 3% of Canadians aged 20 to 79 have Omega-3 Index levels associated with low risk for CHD.

a diagnosis of heart disease, or having had a heart attack. Several reviews and meta-analyses that examined omega-3s and various CHD outcomes have reported inconsistent results: some showed decreased risk for CHD outcomes/events,[4,35] while others showed no benefit.[36,37] Different methodologies contribute to these inconsistencies. The majority of earlier studies considered intake of fish or supplements rather than blood measures of omega-3s. However, not everyone achieves a therapeutic blood level given a fixed dose of omega-3s.[38] Studies that report EPA+DHA intake and those based on measured blood levels may not be comparable.

Further, many previous studies were conducted on populations with elevated cardiovascular risk, not the general population. The beneficial effects of omega-3s may be strongest in already-at-risk groups, or omega-3s may have been recommended for at-risk individuals who, therefore, consume more fish or take supplements. Additionally, the results of earlier research were often clinical outcomes that included cardiac and sudden death and total mortality, outcomes that could not be examined in the present study.

Strengths and limitations

An important strength of this study is the direct measure of RBC fatty acids. Assessment of dietary intake alone may be misleading due to physiological and genetic variability in achieving a desired blood level after a fixed dose of omega-3 supplementation.[38] As well, this analysis was able to adjust for many sociodemographic and lifestyle factors. Finally, the weighted data provide estimates representative of the Canadian adult population.

A number of limitations should be considered in interpreting these results. CHMS budget and logistical constraints meant that the RBC fatty acids could be measured only for a subsample of respondents. The small sample size combined with low prevalence, particularly of Omega-3 Index levels of 8% or more required estimate suppression for certain subgroups and limited the power for statistical testing. The lack of significant results may be due to the small sample size, and thus, reduced power to find statistical associations. As future cycles of CHMS data become available, it will be possible to examine relationships in more depth.

The lack of a measure of serving size for the fish consumed meant that it was not possible to measure actual intake. Nonetheless, the associations observed between fish consumption and the Omega-3 Index suggest that the approach had merit. However, owing to the cross-sectional design, it is not possible to establish causation between intakes and the Omega-3 Index.

Conclusion

Omega-3 Index levels among Canadian adults were higher for women, older people, the Asian population, omega-3-containing supplement users, and people who reported more frequent fish consumption; levels were lower for smokers and obese individuals. When these factors were taken into account, no independent relationships were found between the Omega-3 Index and any CHD-related factor. Information on Omega-3 status will also be available from the 2014/2015 CHMS, thereby allowing for more in-depth analyses using combined data. ■

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Appendix

Table A
Mean selected fatty acid levels, by sex, household population aged 20 to 79, Canada excluding territories, 2012/2013

		Total			Men			Women		
			95% confidence interval			95% confidence interval			95% confidence interval	
Fatty Acid-Trivial Name	Shorthand notation	%	from	to	%	from	to	%	from	to
Lauric acid	C12:0				Less than lower limit of detection					
Myristic acid	C14:0	0.40	0.38	0.42	0.40	0.38	0.43	0.40	0.37	0.42
Palmitic acid	C16:0	23.63	23.46	23.81	23.57	23.32	23.83	23.69	23.48	23.89
Stearic acid	C18:0	17.73	17.44	18.03	17.90	17.57	18.23	17.57†	17.29	17.84
Total saturated fatty acids	Total SFA	42.40	42.01	42.79	42.53	42.11	42.94	42.28†	41.87	42.68
Palmitoleic acid	16:1n-7	0.53	0.47	0.59	0.51	0.42	0.60	0.54	0.47	0.62
Cis-vaccenic acid	18:1n-7c	1.22	1.20	1.25	1.21	1.17	1.25	1.24	1.20	1.27
Oleic acid	18:1n-9c	14.14	14.01	14.28	14.22	13.98	14.45	14.07	13.99	14.15
Total cis-18:1 fatty acids	Total cis-18:1	15.37	15.22	15.51	15.43	15.18	15.67	15.31	15.22	15.39
Total cis-monounsaturated fatty acids	Total cis-MUFA	16.51	16.30	16.71	16.54	16.20	16.88	16.47	16.33	16.62
Palmitelaidic acid	16:1n-7t	0.21	0.17	0.25	0.22	0.18	0.26	0.21	0.16	0.25
Elaidic acid	18:1n-9t	0.04	0.03	0.05	0.04	0.03	0.05	0.04	0.03	0.05
Trans-10-octadecenoic acid	18:1n-8t	0.07	0.06	0.07	0.07	0.06	0.08	0.06	0.06	0.07
Trans-vaccenic acid	18:1n-7t	0.06	0.06	0.07	0.06	0.05	0.07	0.07†	0.06	0.07
Total trans-18:1 fatty acids	Total trans-18:1	0.25	0.22	0.28	0.25	0.21	0.28	0.25	0.23	0.28
Total trans-18:2 fatty acids	Total trans-18:2	0.16	0.13	0.20	0.16	0.13	0.20	0.16	0.13	0.19
Total trans-18:3 fatty acids	Total trans 18:3				Less than lower limit of detection					
Total trans fatty acids	Total TFA	0.62	0.53	0.71	0.63	0.53	0.72	0.62	0.53	0.71
Linoleic acid	18:2n-6	13.14	12.78	13.51	12.80	12.47	13.13	13.47†	12.99	13.96
Gamma-linolenic acid	18:3n-6	0.10	0.09	0.11	0.10	0.09	0.11	0.09†	0.08	0.10
Dihomo-gamma-linolenic acid	20:3n-6	1.83	1.77	1.89	1.88	1.83	1.92	1.78	1.68	1.88
Arachidonic acid	20:4n-6	14.60	14.36	14.84	14.69	14.44	14.93	14.51	14.21	14.80
Adrenic acid	22:4n-6	2.90	2.75	3.04	3.00	2.89	3.12	2.79†	2.60	2.97
Omega-6 docosapentanoic acid	22:5n-6	0.44	0.42	0.45	0.45	0.43	0.46	0.43	0.40	0.45
Total omega-6 polyunsaturated fatty acids	Total n-6 PUFA	33.28	32.82	33.74	33.20	32.65	33.75	33.37	32.93	33.80
Alpha-linolenic acid	18:3n-3	0.29	0.27	0.31	0.27	0.25	0.29	0.31†	0.29	0.33
Eicosatrienoic acid	20:3n-3				Less than lower limit of detection					
Eicosapentaenoic acid (EPA)	20:5n-3	0.76	0.67	0.85	0.74	0.66	0.81	0.78	0.67	0.89
Omega-3 docosapentanoic acid	22:5n-3	2.40	2.33	2.48	2.50	2.43	2.58	2.30†	2.21	2.39
Docosahexaenoic acid (DHA)	22:6n-3	3.74	3.52	3.95	3.60	3.37	3.82	3.87†	3.60	4.15
Total omega-3 polyunsaturated fatty acids	Total n-3 PUFA	7.19	6.94	7.43	7.11	6.86	7.36	7.27	6.93	7.60
Total polyunsaturated fatty acids	Total PUFA	40.47	40.11	40.83	40.30	39.81	40.80	40.63	40.25	41.02

† significantly different from men ($p < 0.05$)
Source: 2012/2013 Canadian Health Measures Survey.