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# Serum lipids of Greenland Inuit in relation to Inuit genetic heritage, westernisation and migration

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**Abstract**

*Background:* The reputed low prevalence of cardiovascular disease among the Inuit has recently been challenged. Studies have shown total cholesterol among the Inuit to differ little from that of western populations and the association between cholesterol and atherosclerosis to be inconsistent. *Methods:* We studied serum lipids in a population survey among 2114 Inuit living in Denmark or in West Greenland. Blood tests were supplemented by structured interviews, anthropometry and measurements of blood pressure. *Findings:* Compared with the general population of Denmark, total cholesterol was higher among Inuit women, while HDL-cholesterol was higher among Inuit men. Triglyceride was lower among Inuit of both sexes. Cholesterol and triglyceride varied according to westernisation, diet, alcohol consumption and smoking. In a multivariate analysis, serum lipids also differed significantly between pure and genetically mixed Inuit: HDL-cholesterol was higher among the genetically pure Inuit, while among men triglyceride was lower and among women total and LDL-cholesterol were higher. *Interpretation:* Among the Inuit, serum lipids are significantly associated with westernisation and genetic heritage. The effect of westernisation is to some extent due to dietary changes. From a cardiovascular health point of view, westernisation within Greenland is associated with unfavourable lipid changes while migration to Denmark is associated with favourable lipid changes.
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*Keywords:* Cholesterol; Diet; Genetics; Greenland; Triglyceride; Westernisation

## 1. Introduction

Mortality from ischemic heart disease has been reported to be somewhat lower amongst the Inuit than amongst western populations while mortality from other cardiovascular diseases is higher. These observations are, however, based on mortality statistics of uncertain validity [1]. The prevalence of atherosclerosis has been estimated similar to that in western populations [2,3] or lower [4,5].

Total cholesterol, high-density cholesterol (HDL), low-density cholesterol (LDL) and triglyceride are important markers for cardiovascular risk, although an autopsy study from Greenland only showed an association between low HDL and atherosclerotic lesions—specifically fatty streaks in the abdominal aorta and only among men [5]. Most studies among the Inuit have shown total cholesterol to be similar to or lower than values from western populations while HDL-cholesterol was considerably higher and triglyceride lower [6–10]. Data on LDL cholesterol concentrations have been inconsistent [7,10,11]. This anti-atherogenic pattern has been attributed to a high consumption of marine mammals and fish. Studies among the Inuit from Greenland and Canada have shown statistically significant direct correlation between a marine diet, estimated by *n*-3 fatty acids in serum or reported consumption of seal, and HDL and inverse associations with triglyceride [10,12]. Studies among the Canadian Inuit further showed direct correlation between serum *n*-3 fatty acids and total and LDL cholesterol [10].

Serum lipid levels are determined by heredity and environmental factors and vary significantly among populations. In the MONICA study, for instance, median total cholesterol among men aged 35–64 ranged from 4.1 mmol/l in

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Beijing to 6.4 mmol/l in Luxembourg [13]. Comparisons of urban and rural populations [14–18] as well as populations migrating from developing to developed countries [19–23] have generally shown an increase in total cholesterol often accompanied by increased LDL-cholesterol [14,16,18,22] and triglyceride [16,18,20,22], while HDL-cholesterol has decreased [14,19], remained constant [16], or increased [20,22]. Most of these studies were comparisons of two cross-sectional surveys but in one study of Ethiopian male migrants to Israel the researchers followed the immigrants for two years and found increasing total and HDL-cholesterol and triglyceride [20]. Another study compared migrants from Punjab (India), to London with their siblings in Punjab and found increased total cholesterol, decreased HDL-cholesterol and no changes in triglycerides in the London study group [19]. Two studies of urbanisation, from Trinidad [14] and Guatemala [18], respectively, found that the changes were less pronounced among women than among men. One study comparing 25 Inuit women living in Denmark with 41 Danish women showed plasma lipid levels to be higher among the Greenlanders although the difference was not statistically significant [24].

The Inuit have gone through an accelerated process of westernisation especially since 1950. Among the most conspicuous changes have been urbanisation, globalisation, a marked decrease in subsistence hunting and fishing, a dietary transition from a traditional diet based on sea mammals to a mixed western diet, reduced physical activity, increased consumption of alcohol and tobacco and increased social stress [25]. The process of westernisation is not necessarily associated with abandonment of Greenlandic identity but comprises the acquisition of certain new habits and lifestyles. Primarily because of the dietary transition, westernisation is expected to influence the Inuit's serum levels of cholesterol in a negative way with respect to cardiovascular risk, in particular decreasing HDL and increasing triglyceride.

The aim of the present study was to analyse the association of serum lipids with westernisation, migration and genetic heritage among Greenland Inuit and Inuit migrants in Denmark. Our hypothesis was that HDL decreased with westernisation, that LDL and triglyceride increased and that this could be explained by dietary changes.

## 2. Methods

### 2.1. Study population and sample

The population of Greenland is 56 000 of which an estimated 90 percent are ethnic Greenlanders (Inuit). Further, an estimated 8000 ethnic Greenlanders live in Denmark permanently or for shorter periods for educational purposes. The Greenlanders are ethnically closely related to the Inuit of Canada and the Alaska and Siberian Inupiat and Yupik, also known as Eskimos. Living conditions differ considerably between Greenland and Denmark and between towns and villages in Greenland. The villages in Greenland are small; subsistence hunting and fishing are important and traditional Greenlandic food makes up a significant proportion of the diet. In the Greenlandic towns, hunting and fishing are important leisure time activities but well supplied shops carry an abundance of imported food, in particular in the capital, Nuuk. In Denmark, the Inuit migrants are well integrated into the Danish society and their life style is similar to that of the general population in a western industrialised country.

Data were collected from 1998 to 2002 among adult Greenlanders living in Denmark, Nuuk (population 14 000), Qasigiannguit (population 1400) and four villages in the district of Uummannaq (population 240–275). In Nuuk, a random sample of the population was invited to participate while in Qasigiannguit and Uummannaq everyone was invited. In Denmark, data was collected in two separate surveys in 1998 and 2002. In 1998, a two-stage procedure was used to identify the Inuit. Firstly, persons born in Greenland were identified from the Central Population Register. In order to approximate the age composition in Greenland, a weighted sample of these was drawn consisting of a random sample of those aged 18–44 years and everyone aged 45 and above. A questionnaire was mailed to the sample and information on ethnicity was obtained from 77%. Only Greenlanders defined as persons with at least one Greenlandic parent were included. A random sample of these was invited to participate in the study [26]. In 2002, persons born in Greenland, aged 34+ were identified in the Central Population Register. A random sample of these was invited to participate in the survey and persons with at least one Greenlandic grandparent were enrolled. From Greenland and Denmark, a total of 3842 Greenlanders aged 18 and above was invited to participate in the study. Information was obtained from 2312 (60%). The participation rate was 53% in Denmark and 67% in Greenland ($P < 0.001$). For the present analyses the study base consisted of 2114 participants aged 25+, with cholesterol measurements and who were not taking cholesterol lowering medication.

The study was approved by the relevant ethical review committees. All subjects had been informed about the study in writing and orally and had given their informed consent in writing prior to enrolment.

### 2.2. Interviews and questionnaires

Data were collected by structured interviews and self-administered questionnaires. The survey questionnaires were developed in Danish and subsequently translated into Greenlandic. The translation procedure included translation by two or more interpreters followed by an independent back translation into Danish and revision of the translation as needed. In Denmark almost all the information was obtained using the survey instruments in the Danish language, while in Greenland almost all information was obtained

in the Greenlandic language. Background information was obtained by mailed questionnaires or personal interviews.

Genetic Inuit heritage was estimated from questions on the ethnicity of the four grandparents and if this information was missing of the parents. It was subsequently recoded as full (at least three grandparents were Greenlanders) or part Inuit (mixed) heritage. Smoking behaviour was categorised into current smokers and non-smokers, comprising never smokers and previous smokers. Participants rated their physical activity level during leisure time summer and winter on a five-point scale ranging from sedentary (read and watch TV) to very active (heavy exercise several times a week). This was subsequently recoded into sedentary, light and heavy activity. Diet was recorded in a food frequency questionnaire comprising 14 different traditional and imported food types. The frequency categories were "daily", "4–6 times a week", "1–3 times a week", "2–3 times a month", "once a month or less often" and "never". The 14 dietary variables were condensed into three by factor analysis as described below.

The consumption of alcohol was recorded by two questions, on the frequency of alcohol consumption and on the number of drinks consumed on the last occasion. This was transformed into a semi-quantitative measure: no consumption of alcohol, less than 14 drinks per week and 14 or more drinks per week.

The participants were categorised according to degree of westernisation based on current place of residence and proficiency in the Danish language. The migrants formed one group irrespective of language ($N = 918$); 98% had lived in Denmark for 3 years or more (average 25.2 years). In Greenland, the most westernised were those who spoke Danish well and who lived in Nuuk ($N = 219$). The least westernised were those who spoke only Greenlandic and who lived in a village or a small town in Greenland ($N = 457$). An intermediate group consisted of the remaining participants from Greenland; most of these lived in Nuuk or Qasigiannguit and spoke some Danish ($N = 468$). Because of the lack of information about their language, 52 of the participants (2.5%) could not be classified. As an additional socio-economic variable, participants' educational level was assessed as no education past primary school, 2 years or less and 3 or more years of education.

### 2.3. Physical measurements

Clinical data were collected by interviews, physical examinations and blood sampling. The clinical examinations took place at the local hospital or in the villages at the health clinic or school. In Greenland and in the 2002 survey in Denmark participants had fasted overnight. In the 1998 survey in Denmark, participants were non-fasting. Height and weight were measured with the participants wearing underwear and socks. On the standing participant, waist circumference was measured midway between the iliac crest and the costal margin. BMI was calculated as weight in kilogram divided by height in metres squared. BMI categories were defined according to WHO's guidelines [27]: normal 18.5–24.9 $kg/m^2$; overweight 25.0–29.9 $kg/m^2$ and obese $\geq$ 30.0 $kg/m^2$.

Blood samples were drawn by venipuncture at normal venous pressure. Blood was collected in Vacutainer Gel tube SST (Serum Separator) BD no. 367788. Whole blood was allowed to rest for at least 30 min and serum was separated by centrifugation for 10 min at 1500 G at ambient temperature. Samples were stored at $-20\,^{\circ}C$ until analyses. Analyses were performed at the Department of Clinical Chemistry, Bispebjerg Hospital, University of Copenhagen, Denmark, by Enzymatic colorimetric tests (Boehringer, Mannheim) using Hitachi 917. The following kits were used: Total cholesterol: CHOD-PAP, Roche 1491458; HDL-Cholesterol plus, Roche 1930648; Triglycerides GPO-PAP, Roche 1730711. LDL values were calculated according to Friedewald's formula. Apart from storage at $-20\,^{\circ}C$ the laboratory procedures were similar to those of the Danish MONICA study, from which published results were used for comparison [28]. Total and HDL cholesterol were analysed in fasting and non-fasting participants, triglyceride and the calculation of LDL only in fasting participants.

### 2.4. Statistical methods

The questionnaires were coded and double entered on the computer. Values outside the permitted range were corrected against the questionnaires. Data processing and statistical analysis was performed using standard statistical software (SAS version 8.2 and SPSS version 11.5).

From information on the consumption of the 14 types of food, three factors with eigenvalues above 1.0 were extracted by principal component analysis followed by Varimax rotation (Factor Analysis procedure of SPSS). High scores on factor 1 were associated with the consumption of seal and fish, high scores on factor 2 with consumption of vegetables and fruit, factor 3 with dairy products. Scores ranged from $-3.6$ to 4.9 (mean = 0 and S.D. = 1).

Statistical procedures included $\chi^2$-test (Table 1), Anova test (Tables 1 and 2) and general linear models (the UNIANOVA procedure of SPSS) (Tables 3 and 4). To approximate a normal distribution, the natural logarithms of the blood lipid levels were used throughout and subsequently back-transformed (except in Tables 3 and 4) for presentation.

## 3. Results

The study population included 2114 Greenlanders aged 25 and above. The mean age of the participants in Greenland was 45.4 years compared with 44.9 years of the non-participants (n.s.); in Denmark the mean age of the participants was 44.4 years and of the non-participants 45.0 years (n.s.). Men were underrepresented in Greenland: 43% among the participants and 57% among the non-participants

Table 1
Distribution of basic variables among population subgroups of Inuit in Greenland and Inuit migrants in Denmark

| Variable | | Least westernised ($N = 457$) Mean (SD) | Intermediate group ($N = 468$) Mean (SD) | Most westernised ($N = 219$) Mean (SD) | Migrants ($N = 918$) Mean (SD) | $P$ |
|---|---|---|---|---|---|---|
| Age (years) | | 48.6 (14.4) | 43.3 (12.0) | 42.5 (10.3) | 44.7 (11.5) | <0.001 |
| BMI (missing 18) (kg/m$^2$) | | 26.3 (5.3) | 26.6 (5.0) | 25.5 (4.2) | 25.2 (4.3) | <0.001 |
| Categorical variables (%) | | | | | | |
| Gender | Men | 43 | 46 | 39 | 27 | |
| | Women | 57 | 54 | 61 | 73 | <0.001 |
| Inuit heritage | Full Inuit heritage | 99 | 94 | 80 | 56 | |
| Missing 99 | Part Inuit heritage | 1 | 6 | 20 | 44 | <0.001 |
| Education | Primary school only | 84 | 47 | 22 | 36 | |
| Missing 183 | 1–2 years | 12 | 38 | 43 | 39 | |
| | 3+ years | 4 | 14 | 36 | 25 | <0.001 |
| Smoking | Non-smokers | 35 | 28 | 34 | 42 | |
| Missing 104 | Smokers | 65 | 72 | 66 | 58 | <0.001 |
| Physical activity | Sedentary | 8 | 12 | 24 | 12 | |
| Missing 161 | Light activity | 71 | 73 | 60 | 73 | |
| | Heavy activity | 21 | 15 | 16 | 15 | <0.001 |
| Consumption of seal or fish | Less than weekly | 12 | 34 | 45 | 54 | |
| Missing 96 | Weekly | 88 | 66 | 55 | 46 | <0.001 |
| Consumption of fresh fruit | Less than daily | 93 | 91 | 69 | 54 | |
| Missing 139 | Daily | 7 | 9 | 31 | 46 | <0.001 |
| Consumption of vegetables | Less than daily | 89 | 82 | 69 | 62 | |
| Missing 129 | Daily | 11 | 18 | 31 | 38 | <0.001 |
| Consumption of milk | Less than daily | 80 | 86 | 81 | 67 | |
| Missing 129 | Daily | 20 | 14 | 19 | 33 | <0.001 |
| Consumption of alcohol | None | 28 | 17 | 15 | 7 | |
| Missing 345 | Less than 14 drinks per week | 57 | 68 | 67 | 74 | |
| | 14+ drinks per week | 15 | 15 | 18 | 19 | <0.001 |

$N = 2062$ excluding 52 participants who could not be classified according to modernisation.

in Greenland ($P < 0.001$) and 27% among the participants and 26% among the non-participants in Denmark (n.s.). Table 1 shows basic characteristics of the participants according to the westernisation groups of the population. They differed according to several basic variables and specifically their dietary habits ranged from frequent consumption of seal or fish and low consumption of vegetables, fruit and dairy products in the least westernised group to less fish, very little marine mammals and more vegetables, fruit and dairy products among the migrants.

Table 2
Serum lipids in Greenland Inuit according to westernisation

| | Total cholesterol[a] | | | HDL cholesterol[a] | | | LDL cholesterol[b] | | | Triglyceride[b] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean[c] | 95% CI[c] | | Mean[c] | 95% CI[c] | | Mean[c] | 95% CI[c] | | Mean[c] | 95% CI[c] | |
| Men | | | | | | | | | | | | |
| Least westernised | 5.85 | 5.68 | 6.03 | 1.62 | 1.55 | 1.69 | 3.70 | 3.55 | 3.86 | 0.94 | 0.88 | 1.00 |
| Intermediate | 5.95 | 5.79 | 6.11 | 1.46 | 1.40 | 1.52 | 3.91 | 3.77 | 4.07 | 1.01 | 0.95 | 1.08 |
| Most westernised | 5.98 | 5.72 | 6.25 | 1.36 | 1.28 | 1.45 | 3.94 | 3.69 | 4.22 | 1.14 | 1.02 | 1.27 |
| Migrants | 5.83 | 5.60 | 6.06 | 1.49 | 1.41 | 1.58 | 3.61 | 3.24 | 4.03 | 1.21 | 1.02 | 1.43 |
| $P$-value | n.s. | | | <0.001 | | | n.s. | | | 0.004 | | |
| Women | | | | | | | | | | | | |
| Least westernised | 5.76 | 5.62 | 5.90 | 1.64 | 1.59 | 1.70 | 3.62 | 3.49 | 3.75 | 0.96 | 0.90 | 1.01 |
| Intermediate | 6.06 | 5.92 | 6.20 | 1.56 | 1.51 | 1.61 | 3.95 | 3.82 | 4.09 | 1.02 | 0.96 | 1.08 |
| Most westernised | 6.01 | 5.80 | 6.23 | 1.52 | 1.44 | 1.59 | 3.91 | 3.70 | 4.13 | 1.08 | 0.98 | 1.17 |
| Migrants | 6.12 | 6.01 | 6.23 | 1.82 | 1.78 | 1.87 | 3.65 | 3.47 | 3.84 | 1.20 | 1.11 | 1.30 |
| $P$-value | 0.001 | | | <0.001 | | | 0.002 | | | <0.001 | | |

Adjusted for age and body mass index by a General Linear Model (mmol/l). Only persons with three or more Inuit grandparents. $N = 1483$ (total and HDL cholesterol); $N = 1024$ (LDL cholesterol and triglyceride).

[a] Fasting and non-fasting participants.

[b] Fasting participants.

[c] Antilogarithm of results of GLM.

Table 3
General Linear Models of logarithms of serum lipids among Greenland Inuit men

| Men | Total cholesterol | | HDL cholesterol | | LDL cholesterol | | Triglyceride | |
|---|---|---|---|---|---|---|---|---|
| | Beta | P | Beta | P | Beta | P | Beta | P |
| Population group | | | | | | | | |
| Least westernised | Reference | | Reference | | Reference | | Reference | |
| Intermediate | 0.006 | n.s. | −0.109 | <0.001 | 0.032 | n.s. | 0.047 | n.s. |
| Most westernised | −0.010 | n.s. | −0.182 | <0.001 | 0.014 | n.s. | 0.147 | 0.04 |
| Migrants | 0.034 | n.s. | −0.016 | n.s. | 0.032 | n.s. | 0.188 | 0.05 |
| Genetic heritage | | | | | | | | |
| Pure Inuit | Reference | | Reference | | Reference | | Reference | |
| Mixed | −0.004 | n.s. | −0.080 | 0.02 | 0.052 | n.s. | 0.180 | 0.02 |
| Alcohol consumption | | | | | | | | |
| None | Reference | | Reference | | Reference | | Reference | |
| 1–13 drinks per week | 0.017 | n.s. | 0.045 | n.s. | −0.005 | n.s. | −0.007 | n.s. |
| 14+ drinks per week | 0.027 | n.s. | 0.149 | <0.001 | −0.025 | n.s. | 0.005 | n.s. |
| Smoking | | | | | | | | |
| Non-smokers | Reference | | Reference | | Reference | | Reference | |
| Smokers | 0.012 | n.s. | −0.025 | n.s. | 0.037 | n.s. | 0.095 | 0.06 |
| Age | 0.003 | <0.001 | 0.003 | <0.001 | 0.002 | 0.070 | −0.005 | 0.007 |
| Body Mass Index | 0.008 | <0.001 | −0.028 | <0.001 | 0.015 | <0.001 | 0.047 | <0.001 |
| Consumption of seal and fish (factor score) | 0.035 | <0.001 | 0.057 | <0.001 | 0.037 | 0.020 | −0.028 | n.s. |

$N = 600$ (total and HDL cholesterol); $N = 407$ (LDL cholesterol and triglyceride).

In Fig. 1 and Table 2, results are presented for 1546 participants with three or more Inuit grandparents only. Fig. 1 compares serum lipids of Inuit living in Greenland and in Denmark with the general population in Denmark [28]. Total cholesterol was higher among the Inuit women than in the Danish women. HDL for men was higher among the Inuit than in the Danish population, while for women the HDL levels among the Inuit migrants were considerably higher than those of the two other populations. There was no difference for LDL, while triglyceride was considerably higher among Danish men than among the Inuit.

The population groups in our study differed significantly with respect to age and obesity, which in many studies have been shown to be strong determinants for blood lipids. In

Table 4
General Linear Models of logaritms of serum lipids among Greenland Inuit women

| Women | Total cholesterol | | HDL cholesterol | | LDL cholesterol | | Triglyceride | |
|---|---|---|---|---|---|---|---|---|
| | Beta | P | Beta | P | Beta | P | Beta | P |
| Population group | | | | | | | | |
| Least westernised | Reference | | Reference | | Reference | | Reference | |
| Intermediate | 0.048 | 0.009 | −0.056 | 0.03 | 0.088 | 0.001 | 0.069 | n.s. |
| Most westernised | 0.037 | 0.09 | −0.079 | 0.009 | 0.070 | 0.04 | 0.074 | n.s. |
| Migrants | 0.067 | <0.001 | 0.105 | <0.001 | 0.038 | n.s. | 0.200 | 0.001 |
| Genetic heritage | | | | | | | | |
| Pure Inuit | Reference | | Reference | | Reference | | Reference | |
| Mixed | −0.069 | <0.001 | −0.074 | <0.001 | −0.075 | 0.02 | −0.043 | n.s. |
| Alcohol consumption | | | | | | | | |
| None | Reference | | Reference | | Reference | | Reference | |
| 1–13 drinks per week | 0.031 | 0.08 | 0.061 | 0.01 | 0.041 | n.s. | 0.055 | n.s. |
| 14+ drinks per week | 0.057 | 0.02 | 0.182 | <0.001 | 0.047 | n.s. | 0.074 | n.s. |
| Smoking | | | | | | | | |
| Non-smokers | Reference | | Reference | | Reference | | Reference | |
| Smokers | 0.015 | n.s. | −0.046 | 0.005 | 0.005 | n.s. | 0.090 | 0.01 |
| Age | 0.006 | <0.001 | 0.003 | <0.001 | 0.006 | <0.001 | 0.003 | 0.02 |
| Body Mass Index | 0.005 | <0.001 | −0.017 | <0.001 | 0.008 | <0.001 | 0.042 | <0.001 |
| Consumption of seal and fish (factor score) | 0.019 | 0.01 | 0.027 | 0.009 | 0.027 | 0.03 | −0.012 | n.s. |

$N = 1094$ (total and HDL cholesterol); $N = 610$ (LDL cholesterol and triglyceride).

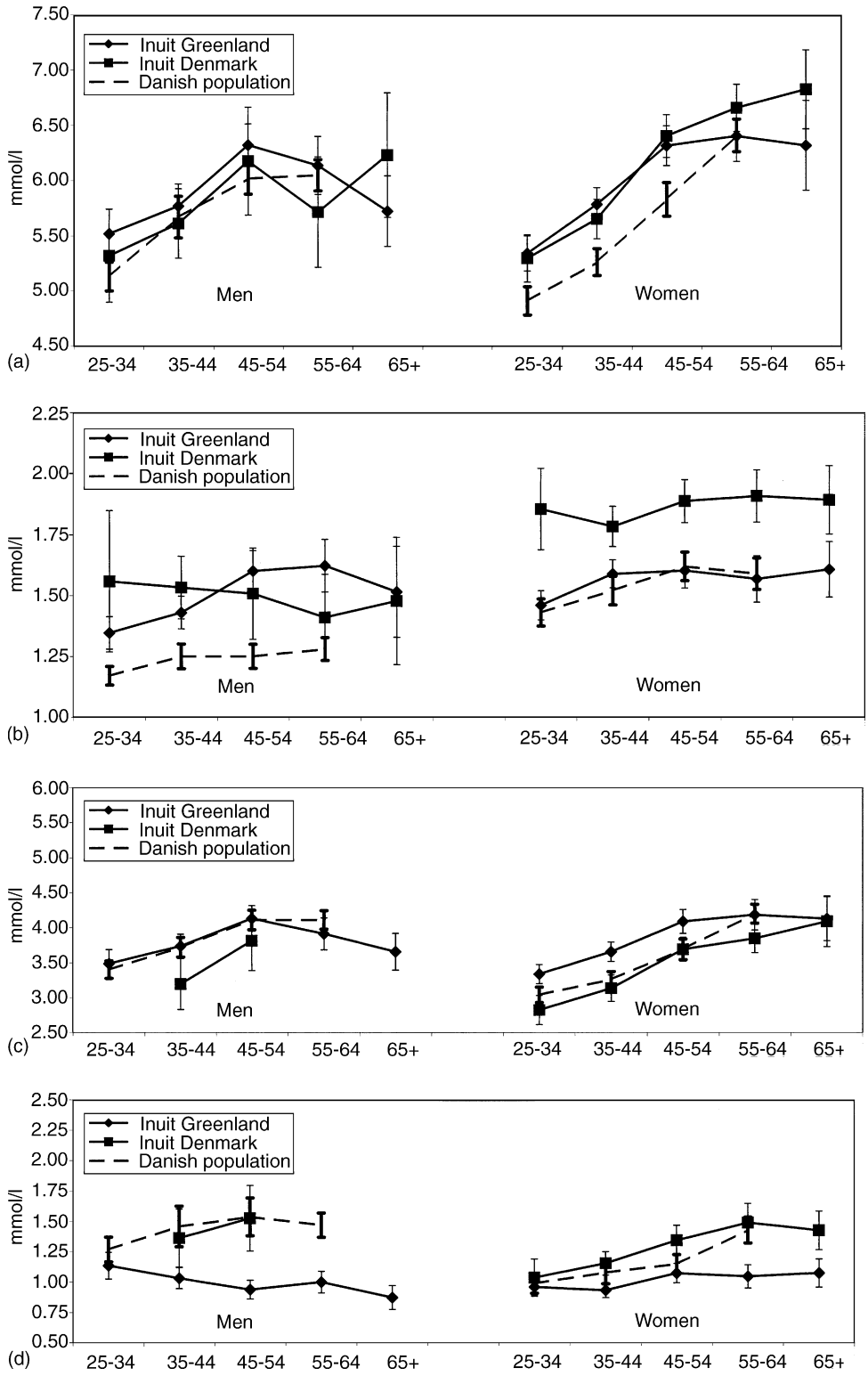


Fig. 1. (a) Total cholesterol and (b) HDL cholesterol by age among Inuit living in Greenland, Inuit living in Denmark and the general population of Denmark. Fasting and non-fasting Inuit participants; fasting Danish participants. Only Inuit with three or more Inuit grandparents were included. (c) LDL cholesterol and (d) triglyceride by age among Inuit living in Greenland, Inuit living in Denmark and the general population of Denmark. Fasting participants. Data points with less than five observations were excluded (certain age groups amongst the male participants). Only Inuit with three or more Inuit grandparents were included.

Table 2 we therefore, compared the westernisation groups after adjustment for age and body mass index. Total cholesterol increased significantly with westernisation for women but remained constant for men. HDL decreased with westernisation within Greenland but increased again among the migrants. LDL showed an opposite pattern to HDL, increasing with westernisation within Greenland but then decreasing again among the migrants, significantly only for women. Triglyceride increased significantly with westernisation among both men and women.

The four westernisation groups differed with respect to a number of variables that might influence serum lipids, including diet, alcohol consumption, smoking, physical activity and education. Consumption of seal and fish was very low among the migrants, while the most westernised women in Greenland and the migrants had a high consumption of vegetables and fruit compared with the other groups. In four multivariate models we also included participants with partly Inuit genetic heritage (Tables 3 and 4).

In the multivariate models, the genetic variable showed several significant associations with serum lipids. For men, HDL was lower among those with mixed heritage while triglyceride was higher. For women, total, HDL and LDL cholesterol were all significantly lower among those with mixed heritage. Consumption of seal and fish was directly associated with total, HDL and LDL cholesterol. Alcohol consumption was directly associated with HDL cholesterol. Finally, female smokers had lower HDL and higher triglyceride than non-smokers. The other dietary variables, physical activity and education were not statistically significant predictors for any of the serum lipids and were excluded from the models. After control for all confounders, the associations between westernisation and serum lipids remained essentially the same as after control for age and body mass index only.

## 4. Discussion

Our results indicate that serum lipids are significantly associated with westernisation and migration among the Greenland Inuit and that additional significant associations exist with consumption of marine mammals and fish, alcohol and smoking. In addition, HDL cholesterol and among women also total and LDL cholesterol, were significantly higher among participants with three or more Inuit grandparents compared with participants with one or two Inuit grandparents.

We had expected a decrease of HDL and an increase of LDL with westernisation. This was found but only within Greenland and for LDL in particular for women. Female Inuit migrants in Denmark had significantly higher HDL levels than those living in Greenland and LDL levels similar to those of the least westernised women in Greenland. For male migrants, HDL levels were similar to those of the least westernised men in Greenland, while there were no differences for LDL. We had furthermore expected triglyceride to increase with westernisation and this proved to be the case. Marine diet was positively associated with total and HDL as well as LDL cholesterol.

Compared with the general population in Denmark, we found the HDL concentrations higher and triglyceride lower among Inuit men, whereas for women total cholesterol was higher among the Inuit. However, female Inuit migrants had significantly higher HDL levels than women in Greenland or the general population in Denmark. HDL was previously also found to be higher among Inuit migrant women than among Danish women [19]. The magnitude of the difference in that study and ours was similar but due to a small sample size the difference was not statistically significant in the first study. These results do not confirm the previously observed pattern of low total cholesterol and triglyceride and high HDL cholesterol among the Inuit compared with western populations [6–10].

The occurrence of apolipoprotein E2 alleles is rare among the Greenland Inuit while the E4 alleles are slightly more frequent that among other populations. The apoE polymorphism, however, only showed a minor influence on the plasma lipid levels [11,29].

Our cholesterol analyses were carried out at the same laboratory but there were certain differences in the procedures regarding specimens from the migrants and the population in Greenland. Many of the migrants were not fasting and the blood was separated and analysed immediately, while the participants in Greenland were mostly fasting and the plasma was frozen at $-20\,^{\circ}C$ after separation and shipped to Denmark for analysis. Furthermore, the migrant samples were collected in 1998–99 and in 2002 while the samples from Greenland were collected in 1999–2001. In order to test the reliability of the laboratory procedure, we compared blood lipids in samples that had been frozen with samples from the same participants that had not been frozen and did not find any difference. It is accordingly presumed that the different procedures do not impede a comparison of the results. Analysis of non-fasting samples was only done for total and HDL cholesterol, which is generally accepted as a valid procedure.

Our results confirm previous findings among the Inuit in Greenland and Canada of a positive association of a marine diet with HDL cholesterol but failed to confirm an association between diet and triglyceride [10,12]. The direct association of a marine diet with total and LDL cholesterol observed in Canada was also supported [10].

Studies of migrants or of urban versus rural populations have shown an inconsistent pattern mostly consisting of increased total cholesterol often accompanied by increased LDL cholesterol and triglyceride, while changes in HDL cholesterol have been inconsistent [14–23]. This pattern was only to a certain extent found among the Inuit, but most of these studies have compared agrarian populations whose diets are not directly comparable to the animal diet of the traditional Inuit.

The opposite associations of westernisation (within Greenland) and migration on HDL and LDL are particularly interesting. The associations persisted after control for diet and other behavioural variables but are probably nevertheless caused by dietary differences. Our dietary questionnaire was primarily designed to measure the traditional marine diet of the Inuit and was perhaps not sensitive enough to differences regarding western dietary items. Furthermore, the traditional Inuit way of preparing meat and fish is boiling in water which is increasingly being replaced by other cooking methods, for instance frying with butter or oil. We have no information on the cooking methods used by the participants.

The high HDL, and for women also total and LDL cholesterol, among full blooded Inuit compared with those of mixed origin suggest a genetically determined high sensitivity to environmentally induced changes in plasma lipids.

Our conclusion is that westernisation has an effect on blood lipids and that this is to at least some extent due to dietary changes. The effects on HDL and LDL cholesterol of westernisation (within Greenland) are unfavourable for cardiovascular health, while those of migration are favourable. This could be caused by a decreased consumption of marine food with westernisation in Greenland and an increased consumption of fruit, vegetables and plant oils among the migrants. We have confirmed the beneficial effect of a marine diet on serum lipids but other, probably dietary, factors seem to be equally or even more important. The effects of westernisation and migration and of diet and genetic determinants of plasma lipids, amongst the Inuit warrant further studies.

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