Diabetes and Impaired Glucose Tolerance Among the Inuit Population of Greenland

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OBJECTIVE — To assess the prevalence of diabetes and impaired glucose tolerance (IGT) among the Inuit population of Greenland and to determine risk factors for developing glucose intolerance.

RESEARCH DESIGN AND METHODS — This cross-sectional study included 917 randomly selected adult Inuit subjects living in three areas of Greenland. Diabetes and IGT were diagnosed using the oral glucose tolerance test. BMI and waist-to-hip ratio were measured and blood samples were taken from each subject. Sociodemographic characteristics were investigated using a questionnaire.

RESULTS — The age-standardized prevalences of diabetes and IGT were 10.8 and 9.4% among men and 8.8 and 14.1% among women, respectively. Of those with diabetes, 70% had not been previously diagnosed. Significant risk factors for diabetes were family history of diabetes, age, BMI, and high alcohol consumption, whereas frequent intake of fresh fruit and seal meat were inversely associated with diabetic status. Age, BMI, family history of diabetes, sedentary lifestyle, and place of residence were significant predictors of IGT.

CONCLUSIONS — The prevalence of diabetes is high among the Inuit of Greenland. Heredity was a major factor, while obesity and diet were important environmental factors. The high proportion of unknown cases suggests a need for increased diabetes awareness in Greenland.

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Studies of the Inuit before the 1980s have shown a low prevalence of diabetes compared with Danish subjects and other Western populations (1–5). A cross-sectional study from Greenland from 1966 that included 4,249 individuals, in which urinary glucose was used as the primary screening test, found three cases of type 2 diabetes (2). A study of clinically diagnosed cases in the district of Upernavik (~1,800 inhabitants) over the 25-year period between 1950 and 1974 found diabetes in only one person. The expected number according to European incidence rates was nine (6). This is the most recent information on diabetes from Greenland.

Surveys over the last 20 years showed increasing, but somewhat differing, prevalence of glucose intolerance among the Inuit in Alaska and Canada (7–17), but the prevalence was still low compared with American Indians (7,17,18). However, all adults received an oral glucose tolerance test (OGTT) in only three population-based studies among Inuit. Mouratoff et al. (3,4) found increasing prevalence of diabetes among Alaska Inuit from 0.7% in 1967 to 5.2% in 1972. Ebbesson et al. (14) found a 6.6% prevalence of diabetes among three Inuit groups in 1994.

Diabetes and impaired glucose tolerance (IGT) are closely associated with insulin resistance. Insulin resistance is partly genetically determined and partly due to modifiable factors such as physical activity, obesity, body fat distribution, and possibly diet. The recorded mortality from ischemic heart disease is low among Greenlanders (19). This may be due to genetic factors. On the other hand, some researchers claim that the Inuit have a genetic potential for developing high incidences of cardiovascular disease and insulin resistance (20,21). Lifestyle factors would then be responsible for the attenuated risk. The aims of the study were to assess the prevalence of diabetes and IGT among groups of Greenlanders living under different environmental conditions and to analyze determinants for diabetes and IGT.

RESEARCH DESIGN AND METHODS

Participants

Data were collected from March 1999 to April 2001 in random samples of adult Greenlanders. The total population of Greenland is 56,000, of which 90% are ethnic Greenlanders (Inuit). Genetically, Greenlanders are Inuit (Eskimos) with a substantial admixture of European, mainly Danish, genes. They are closely related to the Inuit and Yupik in Canada, Alaska, and Siberia. Until the 1950s most Greenlanders made their living by hunting. Over the past decades substantial changes have occurred in Greenland with a rapid westernization, especially in the towns. Today hunting and fishing are important leisure time activities, and tradi-

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Abbreviations: IGT, impaired glucose tolerance; OGTT, oral glucose tolerance test; WHR, waist-to-hip ratio.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

tional Greenlandic food makes up a significant proportion of the diet.

For the survey, three areas of West Greenland were chosen: the capital (Nuuk, 13,500 inhabitants), which has the most westernized living conditions; four villages in a hunting district (Uummannaq, 230–277 inhabitants per village); and a small town with intermediate living conditions (Qasigiannguit, 1,400 inhabitants). The target population was adults aged ≥35 years. In Nuuk, a random sample was drawn from the Central Population Register, supplemented with persons identified from visits to randomly selected households (<7%). Because of this small number, no correction for a possible cluster effect was performed. In Qasigiannguit and Uummannaq the whole Inuit population aged ≥35 years was invited to participate. In Nuuk the participants were invited by mail; in Qasigiannguit and Uummannaq by personal contact to all inhabitants. Only persons with at least one Inuit parent or Inuit self-identification were included in the study.

Verbal and written consent was obtained from all participants. The Ethics Review Committee for Greenland approved the study.

Survey procedure

The diabetes study was a smaller part of a general health survey including lung diseases, allergy, thyroid diseases, and alcohol-related diseases. After overnight fasting the participants attended the survey site between 0700 and 1000 h. Among other things, a 2-h standard 75-g OGTT was performed. Weight and height were measured on a standard balance beam clinical scale with the participants wearing undergarments, and BMI was calculated. On the standing participant, waist circumference was measured midway between the iliac crest and the costal margin, and hip circumference was measured at its maximum.

Plasma samples were immediately put on ice and spun at 4°C within 30 min of sampling. Samples were stored frozen at −20°C and shipped to Denmark for analyses. In participants with a documented history of diabetes, fasting glucose was measured without an OGTT. Glucose tolerance was classified according to World Health Organization (WHO) criteria. Fasting plasma glucose ≥7.0 mmol/l and/or 2-h plasma glucose ≥11.1 mmol/l were taken to indicate diabetes, and IGT was defined as fasting plasma glucose <7.0 mmol/l and 2-h plasma glucose ≥7.8 and <11.1 mmol/l. The laboratory of the Steno Diabetes Center performed the analyses of plasma glucose. Plasma glucose was determined by the hexokinase/G6P-DH method on a Hitachi 912 system.

Questionnaire

Data were collected by structured interviews and self-administered questionnaires. The survey questionnaires were available in Danish and Greenlandic populations and used by the participant according to language preference. The questionnaire contained information on age, sex, and place of residence. Family history of diseases was reported. Inuit blood quantum was estimated from questions on the ethnicity of the four grandparents and if this information was missing for the parents. It was recoded as full Inuit heritage (all grandparents were Inuit) or partly Inuit heritage. Participants completed a food frequency questionnaire about the intake of 14 food items, including traditional (e.g., seal, whale, fish) and nontraditional (e.g., fresh fruit, milk) foods. The frequency of alcohol consumption was reported. Participants were classified as current smokers or nonsmokers, the latter including past smokers.

Using a standardized questionnaire (22), physical activity was graded as *1*) sedentary, *2*) light, *3*) physical activity <4 h per week, *4*) physical activity ≥4 h per week, and *5*) heavy activity several times per week. Grades were recoded on a three-point scale: sedentary (*1*), moderate (*2* and *3*), and heavy physical activity (*4* and *5*). Education was recorded as the highest grade completed.

Statistics

All analyses were performed using SPSS 10.0. Between-group comparisons were performed using independent sample Student's *t* test for continuous variables. The direct method was used to age-standardize the prevalence of diabetes and IGT by geographic area to the total survey population in Greenland. Association of risk factors with diabetes and IGT was tested independently after adjusting for age and sex by logistic regression. To evaluate the association of glucose status with place of residence, multivariate logistic regression was used with age, BMI, waist-to-hip ratio (WHR), family history of diabetes, physical activity, school education, and consumption of seal meat, vegetables, fresh fruit, tobacco, and alcohol as covariates.

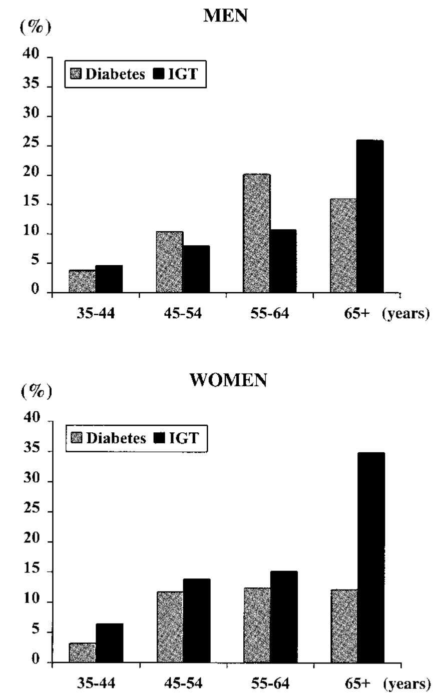

Figure 1—*Age-specific prevalence of diabetes and IGT among men and women.*

RESULTS — A total of 1,345 Inuit subjects aged ≥35 years were invited to participate in the study. Of those, 917 attended the study (68.2%). The participant rate was 66, 72, and 64% in Nuuk, Qasigiannguit, and Uummannaq, respectively ($P = 0.025$). The median age of the sample was 49 years (range 35–86), and 44% were men. Of the subjects, 23 could not be classified with respect to glucose tolerance because of either a total lack of blood samples ($n = 6$) or missing values on the 2-h sample ($n = 17$). Of the 894 subjects examined, 196 (21.9%) met the criteria for glucose intolerance, including 87 persons with diabetes (9.7%). The age-adjusted prevalence of diabetes was 10.8% among men and 8.8% among women ($P = 0.27$). Of those with diabetes, 61 (70%) were not previously aware of their diabetic status. The group with glucose intolerance included 109 subjects with IGT (12.2%). The age-adjusted prevalence of IGT was 9.4% among men and 14.1% among women ($P = 0.03$).

The prevalence of diabetes and IGT

Table 1—*Glucose tolerance status by risk factor categories*

	n	% with diabetes	Adjusted OR (95% CI)	*P*	% with IGT	Adjusted OR (95% CI)	*P*
Place of residence							
Nuuk	337	9.5*	0.60 (0.33–1.07)	0.08	11.9	2.16 (1.02–4.57)	0.04
Qasigiannguit	403	8.2*	0.52 (0.29–0.93)	0.03	13.8	2.51 (1.21–5.20)	0.01
Uummannaq	154	14.5*	1.00		6.1	1.00	
Family history of diabetes							
Yes	95	11.8	3.02 (1.45–6.30)	0.03	18.3	2.46 (1.33–4.55)	0.004
No	794	5.9	1.00		11.4	1.00	
Inuit blood quantum							
Full	771	6.5	1.09 (0.37–3.22)	0.88	12.1	0.73 (0.35–1.51)	0.40
Partly	73	5.6	1.00		15.3	1.00	
Physical activity							
Sedentary	90	10.6	2.15 (0.73–6.35)	0.165	24.7	3.19 (1.25–8.16)	0.015
Moderate activity	577	6.0	1.02 (0.42–2.49)	0.97	11.1	1.14 (0.50–2.62)	0.76
Heavy activity	107	6.8	1.00		7.8	1.00	
Education							
8 years or less	478	9.3	1.00		12.9	1.00	
9-11 years	275	1.9	0.29 (0.11–0.77)	0.013	9.5	1.59 (0.88–2.89)	0.12
High school or more	32	0	0.04 (0.01–9.78)	0.65	12.9	2.92 (0.90–9.49)	0.07
Fresh fruit intake							
≥4 times per week	241	3.8	0.33 (0.15–0.76)	0.009	8.9	0.65 (0.34–1.24)	0.19
1–3 times per week	268	2.7	0.19 (0.08–0.46)	<0.001	13.0	0.83 (0.47–1.45)	0.51
2–3 times per month	88	10.5	0.82 (0.36–1.90)	0.649	11.6	0.86 (0.39–1.94)	0.72
Once monthly or less	200	13.3	1.00		16.8	1.00	
Intake of seal meat							
≥4 times per week	58	8.6	0.88 (0.28–2.77)	0.82	6.9	0.35 (0.11–1.12)	0.07
1–3 times per week	351	8.4	1.31 (0.54–2.40)	0.74	13.3	0.87 (0.49–1.53)	0.63
2–3 times per month	234	4.4	0.64 (0.26–1.56)	0.32	9.6	0.67 (0.35–1.27)	0.22
Once monthly or less	191	6.0	1.00		13.1	1.00	
Smoking status							
Current smoker	567	5.1	0.51 (0.29–0.9)	0.021	10.0	0.65 (0.42–1.01)	0.06
Nonsmoker	289	10.2	1.00		17.2	1.00	
Alcohol consumption							
>3 times per week	38	24.3	17.4 (4.14–72.7)	<0.001	10.8	0.91 (0.27–4.01)	0.87
1–2 times per week	161	7.5	5.19 (1.38–19.5)	0.015	11.9	1.06 (0.54–2.10)	0.86
1–3 times per week	411	6.5	5.01 (1.44–17.4)	0.011	9.5	0.84 (0.47–1.49)	0.54
Less than monthly or never	161	1.9	1.00		18.4	1.00	

Crude prevalences with age- and sex-adjusted ORs. *Both known and previously unknown cases.

increased with age (Fig. 1). The combined prevalence of diabetes and IGT in the population ≥55 years of age was 35.0% (diabetes 15.0%; IGT 20.0%) The prevalence of glucose intolerance among those <55 years of age was 15.0% (diabetes 7.0%; IGT 8.0%).

The age-adjusted prevalences of diabetes and IGT in each of the three areas studied are shown in Table 1. The prevalence of glucose intolerance was similar in the three communities studied. However, in Nuuk and Qasigiannguit, individuals with diabetes made up 37–44% of those with glucose intolerance compared with 70% of individuals in the villages in Uummannaq ($P < 0.001$). Compared with persons with normal glucose tolerance, subjects with diabetes and IGT were older, had higher BMI, and higher WHR (Table 2). Initial univariate analyses compared prevalence of diabetes and IGT among different categories of potential risk factors (Table 1). These analyses were limited to newly diagnosed cases. Diabetes and IGT were more common among those with a family history of diabetes. High rates of diabetes or IGT were also observed among those who had less education, were nonsmokers, were physically inactive, or had a high consumption of alcohol. The number of events among those with partly Inuit blood quantum was too small to draw any meaningful conclusion about the association between Inuit blood quantum and glucose intolerance.

Frequent consumption of fresh fruit was associated with a lower prevalence of diabetes and a protective effect on glucose intolerance of consumption of seal meat at least four times per week was suggested, although it was not statistically significant in the univariate analysis. Other food items had no effect on diabetes or IGT.

We constructed two logistic regression models with diabetes and IGT as de-

Table 2—*Baseline characteristics of the glucose tolerance groups by sex*

	Total study population	Diabetes	P*	IGT	P*	P*†
Age (years)						
Male	50.5 (10.8)	56.0 (9.3)	<0.001	59.9 (12.6)	0.001	0.10
Female	50.0 (11.4)	54.4 (10.6)	0.015	57.1 (13.1)	0.001	0.03
BMI (kg/m^2)						
Male	26.4 (4.6)	27.9 (4.8)	0.026	28.3 (7.1)	0.009	0.07
Female	27.0 (5.6)	31.2 (7.1)	0.001	29.3 (6.0)	0.001	0.16
WHR						
Male	0.94 (0.07)	0.99 (0.08)	0.004	0.98 (0.06)	0.001	0.02
Female	0.90 (0.09)	0.96 (0.08)	0.001	0.95 (0.09)	0.001	0.37

Data are means (SD). *Compared with normal glucose tolerance; †comparison between IGT and diabetes.

pendent variables. Initially, we included all the variables that had shown associations with diabetes or IGT with a P value <0.10 in the univariate analyses in Tables 1 and 2 (Table 3).

Age, BMI, high alcohol consumption, and family history of diabetes were significant predictors of diabetic status, whereas high intake of fresh fruit was conversely associated with diabetes. Age, BMI, family history of diabetes, and a sedentary lifestyle also predicted IGT.

The analyses were repeated for men and women separately. The same variables predicted diabetes and IGT for both sexes. Among men, consumption of seal meat four or more times per week (odds ratio [OR] 0.10, CI 0.01–0.27, P = 0.002) and one to three times per week (OR 0.13, CI 0.02–0.67, P = 0.015) reduced the risk of diabetes compared with the reference group.

CONCLUSIONS — This is the first study of the Inuit population of Greenland in which all participants received a glucose tolerance test. We found a notably high prevalence of diabetes (9.7%) and IGT (12.2%). The prevalence of diabetes among Greenlanders is apparently higher than that among the Inuit population of Alaska (14). However, since the Alaska-Siberia Project was performed, the diagnostic criteria of diabetes have changed with lowering of the diagnostic threshold for fasting glucose. Using the WHO 1985 recommendations in our study, the prevalence of diabetes would be 7.3%, thus similar to the prevalence in Alaska. The age distribution in the two studies was similar.

Surprisingly, the prevalence of diabetes in Uummannaq was higher than that in the towns of Nuuk and Qasigiannguit, but the multivariate analysis showed no effect of region. One obvious source of misclassification is that some of the participants could be nonfasting. We instructed all participants to fast. Comparison of the proportion of cases diagnosed using only the fasting value of plasma glucose showed no difference between the regions. Thus, it is unlikely that misclassification could explain the high diabetes prevalence in the villages. The differences must be due to the distribution of risk factors, such as heredity, age, obesity, low intake of fruit, and alcohol consumption. Furthermore, inbreeding due to relative isolation of the population could be a possible explanation for the high prevalence of diabetes in the villages. In other areas of Greenland, consanguinity is the course of large familial aggregations of malformations and inborn errors of metabolism (23).

However, overestimation of the diabetes prevalence in the villages due to selection bias cannot be excluded. Some of the Greenlanders who could have participated in our study left their villages for extended periods to hunt. This group of potential participants are more likely to be physically active and to eat traditionally and, therefore, are less likely to have diabetes.

The ratio between IGT and diabetes is higher in the towns than in the villages in our study, similar to the pattern in most countries (24). The ratio between IGT and diabetes is considered to predict the rising prevalence of type 2 diabetes in developing countries (25). The high prevalence of IGT in Qasigiannguit and Nuuk may indicate a potential for a further increase in the number of diabetic patients. In the villages, the prevalence of IGT is much lower than that of diabetes, possibly implying that genetically susceptible persons already fully manifest the disease. However, the relationship of IGT to diabetes prevalence appears to be complex,

Table 3—*Determinants of diabetes and IGT in two multiple logistic regression models**

	Diabetes vs. NGT		IGT vs. NGT	
Dependent variable	OR	95% CI	OR	95% CI
Age (per year)	1.05	1.01–1.09	1.08	1.05–1.11
BMI (per unit)	1.14	1.07–1.21	1.10	1.05–1.15
Family history of diabetes (Yes = 1, No = 0)	2.99	1.06–8.41	3.17	1.55–6.47
Physical activity				
Sedentary	1.88	0.46–7.65	5.53	1.75–17.4
Moderate activity	1.16	0.40–3.32	1.87	0.76–4.60
High activity	1.00		1.00	
Consumption of fresh fruit				
≥4 times per week	0.21	0.07–0.60	0.59	0.27–1.32
1–3 times per week	0.16	0.06–0.43	0.59	0.29–1.17
2–3 times per month	0.54	0.19–1.48	0.63	0.24–1.65
Once monthly or less	1.00		1.00	
Consumption of alcohol				
≥3 times per week	34.48	6.65–178.9	1.88	0.47–7.52
1–2 times per week	5.51	1.26–24.14	1.09	0.48–2.50
1–3 times per month	4.25	1.06–16.93	0.97	0.48–1.93
Less than monthly or never	1.00		1.00	

*The following variables were excluded by backwards selection: sex, place of residence, WHR, education, intake of seal meat, and smoking status. NGT, normal glucose tolerance.

and speculations must be guarded in the absence of longitudinal data.

Of the persons with diabetes, 70% were not previously aware of their diabetic status, which is more than in European populations (24). The proportion of previously undiagnosed cases was higher in Qasigiannguit and the villages of Uummannaq than in Nuuk. The high proportion of unknown cases may be influenced by several factors, including the prevalence of symptoms in untreated cases, lack of awareness of diabetes in the health care system, and regional differences in access to diabetes health care. The present study was a health survey focusing on many different diseases and not only diabetes; thus, we do not expect any over- or undersampling of individuals with specific diseases. The health care system in Greenland is free, and it is unlikely that individuals with known diabetes would attend the study to have their blood glucose tested.

Risk factors for diabetes in this study include age, positive family history, overall obesity, lack of physical activity, diet, and alcohol consumption. Obesity is associated with both diabetes and IGT. Increasing prevalence of obesity has also paralleled the increased prevalence of glucose intolerance among the Inuit populations of Canada and Alaska (14,15,17, 26). Adjusted for BMI, WHR was not associated with diabetes or IGT.

The results indicated a protective effect of intake of fresh fruit on glucose tolerance. A protective effect of dietary seal meat on diabetes prevalence was found in men only. The inconsistent findings of a protective effect of seal meat on glucose intolerance may be due to limitations in the food frequency questionnaire. The food frequency questionnaire did not detail amounts consumed, so specific nutrient intakes cannot be computed. With respect to possible biases, the apparent protective effect of intake of fresh fruit may be a marker for an undefined factor, for example socioeconomic status or healthy behavior. We found no effect on diabetes or IGT from dietary intake of other sea mammals or fish. Among the Inuit population in Alaska the consumption of seal oil and salmon was associated with a reduced risk of glucose intolerance (27). Ebbesson et al. (28) noted significantly lower concentrations of some ω-3 fatty acids and some ω-6 fatty acids in individuals with abnormal glucose tolerance, indicating an association between a low consumption of fish and sea mammals and the development of insulin resistance. However, only a long-term prospective study can clarify whether there is an effect of the traditional Inuit diet on glucose tolerance.

Lack of physical activity is also a strong predictor for the development of diabetes and IGT in other studies (29). Physical inactivity showed an independent association with prevalence of IGT and diabetes, although it was not statistically significant for the latter. The lack of a statistically significant effect may be a result of the use of a questionnaire rather than a direct measure of physical activity; the reliability and validity may be relatively low (30). So far no questionnaire has been developed to assess physical activities in Inuit communities for epidemiological purposes. Frequent intake of alcohol was associated with increased risk for diabetes. The interpretation of these results, however, is difficult. Drinking patterns in Greenland differ from those in Western societies, and is characterized by binge drinking rather than a continuous consumption. The group of frequent drinkers probably comprises both those that consume excessive alcohol and those with moderate daily to weekly alcohol intake. In addition the number of persons in this group was very small.

The present study found a high prevalence of diabetes and IGT among the Greenland population. Heredity was a major factor, while obesity, lack of physical activity, and diet were the important environmental factors. The survey underlined the need for increased awareness of diabetes and for intervention against diabetes and similar lifestyle-related diseases in Greenland.

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