Respiratory function impairment and cardiopulmonary consequences in long-time residents of the Canadian Arctic

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Spirometry, roentgenography and electrocardiography were performed during community health surveys in 1976–78 in 176 Inuit and other long-time residents of the northeastern (Arctic Bay) and western (Inuvik) Canadian Arctic, and the results were related to age, ethnic origin, occupation and history of climatic exposure, smoking and hospitalization for tuberculosis.

In Arctic Bay the young men showed excellent respiratory function, normal-sized pulmonary arteries and normal electrocardiograms, but abnormalities of all three types were increasingly frequent and severe after age 25. The forced mid-expiratory flow (FMF) fell to less than 50% of the norm by age 40, and dilatation of the pulmonary artery, hypertrophy of the right ventricle, right bundle branch block and a pseudoinfarction pattern on the ECG were frequently associated.

In contrast, the men in Inuvik, an urbanized centre, maintained above normal respiratory function until age 40, and the FMF and pulmonary artery diameter remained normal in the older men except for Inuit and white trappers over 60 years old who had run fox trap lines along the Arctic coast in the 1920s and 30s.

These data suggest that inhalation of extremely cold air at maximum ventilation may be a prime factor in the chronic obstructive lung disease of Inuit hunters, whereas smoking has only a minor role and hospitalization for tuberculosis appears to protect from rather than contribute to this disorder.

Des examens spirométriques, radiologiques et électrocardiographiques ont été pratiqués au cours d'une enquête sur la santé communautaire menée entre 1976 et 1978 chez 176 Inuits et autres habitants de longue date du nord-est (Arctic Bay) et de l'ouest (Inuvik) de l'Arctique canadien; les résultats ont été reliés à l'âge, l'origine ethnique, l'occupation et l'exposition aux intempéries, l'usage du tabac et l'hospitalisation pour la tuberculose.

À Arctic Bay les hommes jeunes montrèrent une excellente fonction respiratoire, des artères pulmonaires de calibre normal et des électrocardiogrammes normaux; toutefois, les anomalies des trois types devenaient de plus en plus fréquentes et graves après l'âge de 25 ans. À compter de l'âge de 40 ans le débit expiratoire forcé médian (DFM) était abaissé à moins de 50% de la norme, et une dilatation de l'artère pulmonaire, une hypertrophie du ventricule droit, un bloc de branche droit et un tracé électrocardiographique de pseudo-infarctus étaient souvent associés.

Au contraire, les hommes d'Inuvik, un centre urbanisé, avaient maintenu une fonction respiratoire au-dessus de la normale jusqu'à l'âge de 40 ans. Le DMF et le diamètre des artères pulmonaires étaient demeurés normaux chez les hommes plus âgés, sauf pour les Inuits et les trappeurs blancs de plus de 60 ans qui avaient dressé les chausse-trapes pour les renards le long des côtes arctiques au cours des années 1920 et 1930.

Ces résultats indiquent que l'inhalation à capacité respiratoire maximale d'air extrêmement froid peut être un facteur de première importance pour le développement des troubles ventilatoires obstructifs chroniques chez les chasseurs inuits, alors que l'usage du tabac n'y joue qu'un rôle mineur et que l'hospitalisation pour tuberculose semble protéger plutôt que contribuer à cette affection.

There has been much interest in the chronic lung condition so commonly seen in adult Inuit as to have been labelled "Eskimo lung" by Wherrett many years ago (personal communications).

In a field study in the Eastern Arctic Beaudry[1] found marked lung function impairment in adults of both sexes, which he related to heavy smoking. How-

The illustration on the cover of this issue of the Journal, supplied by Dr. Schaefer, depicts the hard work of sled travel in the eastern Arctic; the men must push and brake with feet and body to control the sled through rough ice.

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ever, he also noted an unexplained additional progressive decrease in maximal mid-expiratory flow in older men.

The possibility that one of the antecedents of this condition was repeated attacks of acute viral respiratory tract disease in infancy and early childhood was raised by Fleshman, Wilson and Cohen,[2] who found a high prevalence of bronchiectasis in Alaskan native children when the prevalence of tuberculosis had declined. In the Canadian Arctic the increased frequency of recurrent respiratory tract infections in children was related to the change in infant feeding from breast to bottle,[3,4] but this could not account for the marked obstructive lung disease found most often in middle-aged and elderly Inuit men of the central and eastern Arctic, where bottle-feeding had spread only during the previous two decades. Increased diameter of the pulmonary arteries, right ventricular hypertrophy and right bundle branch block, all well recognized cardiovascular consequences of chronic lung disease, were also found to be common in elderly men in the central and eastern Canadian Arctic.[5,6]

Many Arctic hunters with the typical pulmonary and cardiovascular features of Eskimo lung relate their respiratory problems to distinctly remembered episodes of "freezing the lungs". Although inclined to dismiss such statements as the result of secondary event fixing tendencies, we have been impressed that these features occurred earlier and were more severe in men who for much of their life had continued to hunt and travel extensively in winter in the traditional manner, by dogteam, and therefore had to breathe very cold air while doing heavy physical work or bracing severe storms.

This impression was lifted above the anecdotal level when we found that impairment of respiratory function and related cardiovascular abnormalities were less frequent in Inuit women and those Inuit men who, owing to long-term employment, did little hunting in the winter.[5,6]

Surveys of general health conditions in two Arctic communities widely differing in lifestyle and in the degree and duration of acculturation afforded an opportunity to accumulate more elaborate data on this question. This paper presents these data in support of the hypothesis that breathing very cold air while doing heavy work contributes to chronic obstructive lung disease in Inuit men.

Materials and methods

Three general and occupational health surveys were carried out between 1976 and 1978 at Arctic Bay, Inuvik and Nanisivik (Fig. 1).

Arctic Bay is an Inuit settlement in northeastern Baffin Island. In 1976 it had a population of approximately 360. These people had lived in hunting camps in the area until the middle and late 1960s and were still leading a relatively traditional life, including extensive travel by dogteam throughout the winter.

Inuvik, the regional centre for the Mackenzie delta, had a total population of approximately 3500 people, including some 550 Inuit and 300 Indians and Métis, who had lived a rather sedentary life since the town was built in the mid-1950s. During the preceding two decades most of the native people had engaged in muskrat trapping, which involved only limited winter travel in the relatively storm-protected delta; only Inuit over 60 years of age and some of the old white trappers had travelled extensively in the winter along the stormy Arctic coast seeking Arctic fox in the 1920s and 30s.

Nanisivik is a new community based on a lead–zinc mining operation on Strathcona Sound, 27 km by road northeast of Arctic Bay. It is populated largely by white miners and their families from southern Canada and by a few Inuit miners recruited mainly from larger settlements in the southeastern Arctic. At the time of our survey the few Arctic Bay people who worked at Nanisivik commuted daily from Arctic Bay.

Subjects

For the general health survey, which is described elsewhere,[4] we examined more than 90% of the Arctic Bay population and one third of the native and long-term white residents of Inuvik, selected at random. In addition, white and Inuit miners were examined in Nanisivik.

Table I shows the geographic and ethnic origin as well as the age of 176 men from whom we obtained spirograms, chest roentgenograms and electrocardiograms during the three surveys. Details of past work and hunting, pulmonary infection, hospitalization for tuberculosis and smoking were recorded.

Spirometry

Single-breath wedge bellows spirometers were used. During the initial 1976 survey in Arctic Bay and Nanisivik we used the small, portable McKesson–Scott machine (McKesson Appliance Co., Toledo,

FIG. 1—Location of communities in which general and occupational health surveys were carried out. Interrupted line indicates Arctic Circle; unlabelled stars indicate Whitehorse (left), Yellowknife (top centre), Edmonton (bottom centre) and Churchill (right).

Ohio), but for the 1977 survey at Inuvik and the repeat survey in 1978 at Arctic Bay and Nanisivik the now more commonly used Vitalograph (Vitalograph Limited, Buckingham, England), which is larger, was available. Less than one third of the subjects from Arctic Bay and Nanisivik underwent spirometry only with the McKesson–Scott machine. Comparison of the tracings obtained in 1978 with both types of equipment in 30 subjects revealed no consistent differences in forced expiratory volume in the first second (FEV$_1$), forced vital capacity (FVC) or forced mid-expiratory flow* (FMF). Both machines provided time–volume tracings from which standard functional measurements were made.

Table I—Geographic, ethnic and age distribution of 176 men in the eastern and western Canadian Arctic who underwent pulmonary function studies in 1976–78

	No. of men				
	Inuit		Western Arctic		
Age (yr)	NE*	SE†	Inuit	Indian	Whites of Inuvik and Nanisivik
16-19	10	1	3	1	–
20-24	12	3	1	1	4
25-29	21	3	4	0	4
30-39	27	5	1	2	6
40-49	12	1	10	–	5
50-59	8	–	6	3	1
60-69	5	–	2	1	3
70+	1	–	4	2	3
All ages	96	13	31	10	26

*From the northeastern Arctic, mostly the Arctic Bay area.
†From the southeastern Arctic, mostly Frobisher Bay and southern Baffin Island.

Tests were performed in all three surveys by the same personnel. They were repeated until no further improvement was achieved, then the best curve was used for calculations. All spirometric readings were expressed as values at normal body temperature (37°C) and normal barometric pressure (760 mm Hg), with the air saturated with water vapour (BTPS values), and

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*This is the internationally accepted term; previously used alternatives include maximal mid-expiratory flow or flow rate (MMF, MMFR or MMEFR) and the average flow during the middle two quarters of the volume segment of the forced expiratory spirogram (FEF$_{25\%-75\%}$).

Table II—Spirometric findings in the men: actual measurements*

	Mean ± standard deviation (SD)				
Age (yr), geographic/ ethnic group (and no.)	Height (cm)	FEV$_1$ (ml)	FVC (ml)	FEV$_1$/FVC (%)	FMF (ml/s)
16-19					
NE Inuit (10)	163.3 ± 6.2	4599 ± 704	5260 ± 803	87.5 ± 4.0	5269 ± 1400
SE Inuit (1)	153	3823	4510	85	3696
Inuvik natives (4)	169.3 ± 3.6	4777 ± 935	5357 ± 935	89.0 ± 4.7	5841 ± 1890
20-24					
NE Inuit (12)	165.9 ± 3.5	4459 ± 539	5253 ± 660	85.0 ± 3.8	4554 ± 810
SE Inuit (3)	165.3 ± 2.6	4632 ± 187	5519 ± 253	84.0 ± 1.0	5544 ± 220
Inuvik natives (2)	173.5 ± 4.9	4516 ± 396	5363 ± 968	85.0 ± 8.5	4708 ± 80
Whites (4)	181.5 ± 4.2	4839 ± 275	5921 ± 363	82.3 ± 7.3	4862 ± 990
25-29					
NE Inuit (21)	165.7 ± 4.4	4178 ± 748	5089 ± 814	82.0 ± 8.5	4213 ± 1400
SE Inuit (3)	161.8 ± 2.9	4759 ± 363	5555 ± 440	85.7 ± 3.8	5467 ± 890
Inuvik natives (4)	169.5 ± 6.3	4766 ± 957	5756 ± 1309	85.3 ± 2.5	5390 ± 1570
Whites (4)	179.1 ± 7.3	5308 ± 572	6653 ± 528	80.0 ± 9.0	5335 ± 1500
30-34					
NE Inuit (12)	163.8 ± 4.3	3710 ± 803	4730 ± 759	78.0 ± 7.5	3311 ± 1390
35-39					
NE Inuit (15)	162.5 ± 4.4	3023 ± 891	4052 ± 1001	74.2 ± 9.0	2332 ± 1020
30-39					
SE Inuit (5)	164.9 ± 5.0	4378 ± 770	5500 ± 1045	80.6 ± 2.4	4257 ± 670
Inuvik natives (3)	171.3 ± 8.7	4150 ± 825	5508 ± 594	76.0 ± 15.4	4719 ± 2280
Whites (6)	170.1 ± 6.1	3804 ± 473	5234 ± 539	72.8 ± 7.8	3267 ± 280
40-49					
NE Inuit (12)	160.3 ± 6.4	2256 ± 836	3406 ± 836	65.1 ± 12.4	1639 ± 1050
SE Inuit (1)	158	3300	4180	80	2651
Inuvik natives (10)	170.5 ± 7.5	3664 ± 539	4687 ± 671	78.3 ± 4.7	3454 ± 1000
Whites (6)	175.5 ± 6.9	3939 ± 385	4998 ± 561	79.2 ± 7.4	3410 ± 1050
50-59					
NE Inuit (8)	159.7 ± 5.9	2223 ± 715	3246 ± 1089	67.2 ± 6.7	1309 ± 560
Inuvik natives (9)	167.9 ± 4.8	3313 ± 715	4184 ± 781	78.9 ± 4.2	3377 ± 1120
Whites (1)	166	2772	3740	74	2055
60-69					
NE Inuit (5)	156.5 ± 5.7	1734 ± 528	2706 ± 506	63.6 ± 15.3	1078 ± 530
Inuvik natives (3)	168.7 ± 2.4	3069 ± 198	4235 ± 385	72.3 ± 3.5	2343 ± 319
Whites (2)	176.5 ± 5.0	1854 ± 950	3262 ± 590	55.0 ± 18.4	1059 ± 540
70+					
NE Inuit (1)	160	963	2090	46.1	374
Inuvik natives (6)	166.8 ± 5.1	2073 ± 979	3077 ± 1474	67.5 ± 6.5	1322 ± 616
Whites (3)	174.7 ± 9.8	1972 ± 41	2871 ± 70	59.0 ± 4.6	1403 ± 360

*Expressed as values at normal body temperature (37°C) and normal barometric pressure (760 mm Hg), with the air saturated with water vapour (BTPS values). FEV$_1$ = forced expiratory volume in the first second; FVC = forced vital capacity; FMF = forced mid-expiratory flow.

were compared with the prediction nomogram of BTPS spirometric values in healthy men derived from Morris, Koski and Johnson.[7]

Chest roentgenography

A total of 144 posteroanterior chest roentgenograms were made at the standard distance of 1.83 m; another 28 films were made at a distance of 1.22 m, so for these a correction factor of 0.967 was used. The diameter of the descending branch of the right pulmonary artery was measured and recorded in millimetres. In 15% of the films the descending branch of the left pulmonary artery was more readily defined and therefore measured. No consistent difference was noted between left and right measurements. In 10% of the subjects the arteries on both sides were indistinct and thus unsuitable for measurement.

Electrocardiography

Twelve-lead electrocardiograms (ECGs) were made with a standard portable machine (Cardiopan Electrocardiograph, model 531; Fred Liechti, Berne, Switzerland).

Results

The spirometric data for the native and non-native groups are shown as actual measurements in Table II and in relation to the height- and age-specific nomogram in Table III. The few Inuvik Indians were included with the Inuvik Inuit as their spirometric findings were similar up to 60 years of age.

Table II shows that the FEV_1, FVC, FEV_1/FVC and FMF were similar in all the groups of men aged 16 to 24 years despite marked differences in height, the eastern Arctic Inuit being 5 to 10 cm shorter than the western Arctic natives and 10 to 15 cm shorter than the white subjects.

Table III demonstrates that the decrease in ventilatory capacities with age was greatest for the FMF, which fell below expected norms in northeastern Arctic Inuit men after age 30 but remained normal or above normal in the Inuit men from the southeastern Arctic to age 40 and in those from the Mackenzie delta until age 60. The change in the diameter of the pulmonary artery appears to reflect very well the course of the FMF, our single best indicator of respiratory function impairment in Inuit.

Table III—Spirometric findings in the men: percentages of expected values* and diameter of pulmonary artery

Age (yr), geographic/ ethnic group (and no.)	Mean ± SD				
	% of expected value				Pulmonary artery diameter, mm (and no. of subjects)
	FEV_1	FVC	FEV_1/FVC	FMF	
16–19					
NE Inuit (10)	112.5 ± 13.2	108.5 ± 13.1	109.2 ± 5.1	111.4 ± 28.4	13.3 ± 0.9 (9)
SE Inuit (1)	104	107	106	91	13 (1)
Inuvik natives (4)	111.5 ± 19.6	104.8 ± 14.4	111.3 ± 5.6	122.0 ± 39.4	13 (1)
20–24					
NE Inuit (12)	109.1 ± 11.8	105.4 ± 10.6	106.1 ± 4.7	94.2 ± 16.5	14.7 ± 1.4 (10)
SE Inuit (3)	114.0 ± 3.0	113.0 ± 2.7	105.0 ± 1.0	120.0 ± 4.4	13.3 ± 1.1 (3)
Inuvik natives (2)	104.0 ± 7.1	101.0 ± 15.6	106.5 ± 10.6	97.5 ± 2.1	14.5 ± 2.1 (2)
Whites (4)	104.0 ± 8.3	101.5 ± 7.0	103.0 ± 9.0	95.8 ± 17.2	13.0 ± 0.9 (3)
25–29					
NE Inuit (21)	105.4 ± 17.8	105.6 ± 14.6	102.4 ± 10.6	95.8 ± 31.9	15.8 ± 1.4 (19)
SE Inuit (3)	126.7 ± 6.1	122.7 ± 6.7	107.0 ± 4.4	127.0 ± 17.8	15.3 ± 1.5 (3)
Inuvik natives (4)	114.8 ± 17.2	109.8 ± 13.7	106.3 ± 3.3	118.0 ± 29.7	14.3 ± 2.5 (2)
Whites (4)	119.5 ± 18.0	118.8 ± 13.6	100.0 ± 11.2	112.5 ± 33.9	14.3 ± 1.5 (3)
30–34					
NE Inuit (12)	100.3 ± 20.5	103.3 ± 14.0	102.9 ± 9.9	79.9 ± 32.9	16.1 ± 1.6 (10)
35–39					
NE Inuit (15)	84.4 ± 24.9	91.3 ± 21.6	97.9 ± 11.9	58.3 ± 26.2	17.3 ± 1.3 (14)
30–39					
SE Inuit (5)	121.0 ± 16.5	120.4 ± 18.8	106.4 ± 3.2	106.8 ± 15.9	14.9 ± 0.7 (5)
Inuvik natives (3)	105.7 ± 18.2	111.7 ± 3.5	100.0 ± 20.0	112.0 ± 51.1	15.2 ± 0.8 (3)
Whites (6)	98.2 ± 14.4	107.3 ± 14.4	96.2 ± 10.3	77.5 ± 20.5	12.7 ± 1.4 (5)
40–49					
NE Inuit (12)	71.4 ± 25.2	85.2 ± 17.2	87.1 ± 16.7	46.4 ± 29.3	18.6 ± 1.9 (11)
SE Inuit (1)	107	108	106	76	– (1)
Inuvik natives (10)	103.3 ± 17.1	101.1 ± 14.2	104.5 ± 6.3	90.2 ± 24.9	15.7 ± 1.1 (10)
Whites (6)	106.2 ± 11.9	101.8 ± 9.9	105.8 ± 9.8	90.3 ± 31.5	12.7 ± 0.6 (3)
50–59					
NE Inuit (8)	79.0 ± 18.2	86.4 ± 21.9	93.0 ± 9.3	43.7 ± 15.8	18.3 ± 1.2 (7)
Inuvik natives (9)	107.7 ± 24.7	100.1 ± 21.2	108.9 ± 5.2	106.1 ± 32.4	15.9 ± 1.2 (9)
Whites (1)	89	89	102	62	16.4 (1)
60–69					
NE Inuit (5)	67.3 ± 18.6	77.0 ± 11.1	89.8 ± 21.5	39.6 ± 17.5	19.5 ± 1.5 (5)
Inuvik natives (3)	106.0 ± 9.6	103.7 ± 10.0	102.3 ± 4.5	81.3 ± 12.7	16.8 ± 1.6 (3)
Whites (2)	59.0 ± 28.3	71.0 ± 11.3	77.5 ± 26.2	37.5 ± 17.7	21.7 ± 0.2 (2)
70+					
NE Inuit (1)	40	66	66	15.4	20.3 (1)
Inuvik natives (6)	88.8 ± 35.4	84.8 ± 39.0	96.5 ± 4.9	61.8 ± 30.0	18.3 ± 2.8 (6)
Whites (3)	75.3 ± 11.5	70.7 ± 8.4	98.7 ± 6.7	61.7 ± 12.3	20.8 ± 1.2 (3)

*Derived from height- and age-specific nomogram of Morris, Koski and Johnson.[7]

Fig. 2 depicts the inverse relation of these two measures in the two largest groups — the natives from the northeastern and western Arctic. The values were similar in the younger men (well within or even above the normal range) but separated significantly in middle age: after age 35 the men from Arctic Bay averaged less than 60% of the expected FMF, and their mean pulmonary artery diameters exceeded 17 mm; however, in Inuvik similar values were found only in men over 60 years of age. The remarkably mirror-image course of both types of curves in the two groups attests to the close relation of respiratory function impairment to pulmonary hypertension in northern hunters.

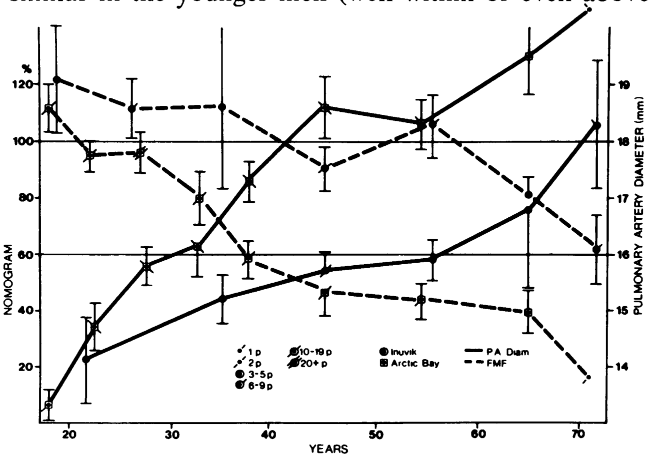

FIG. 2—Relation of respiratory function to pulmonary artery diameter in native men in Inuvik and Arctic Bay. Left ordinate provides scale of observed values as percentages of expected values (mean ± standard error of the mean); upper horizontal line indicates standard of nomogram for forced mid-expiratory flow (FMF) by Morris, Koski and Johnson;[7] and lower horizontal line indicates upper limit of normal (lower limit 9 mm) for diameter of pulmonary artery (PA) in chest roentgenograms of a large series of North American men.[8] Crossing of the FMF and PA curves indicates marked respiratory impairment and related abnormality of pulmonary circulation; men from Arctic Bay entered this stage between ages 30 and 40, but men from Inuvik did so only after age 60.

Some observations in the smaller groups recorded in the tables but not depicted in Fig. 2 are noteworthy even if the small numbers make evaluation difficult. First, the southeastern Arctic Inuit showed (as did the Inuvik natives) no deterioration of respiratory function and no enlargement of the pulmonary arteries in middle age. Second, all the white miners, including those with 2 to 20 years' experience of mining hard rock, had normal spirograms except for two who smoked heavily. Third, the old white trappers living in Inuvik who had spent a decade or more in their earlier years hunting fox along the western Arctic coast had decreases in the FMF similar to those in the old Inuit (to less than 50% of the normal range).

We had found in previous examinations of central and eastern Arctic hunters an unusual prevalence of right ventricular hypertrophy, incomplete and complete right bundle branch block, extreme clockwise rotation of the heart and "pseudoinfarction" patterns in association with impaired lung function and pulmonary artery enlargement.[5,6] We therefore analysed the spirometric, roentgenographic and electrocardiographic findings in conjunction with the pulmonary artery

Table IV—Association of increased pulmonary artery diameter with spirometric, roentgenologic and electrocardiographic abnormalities

	Geographic/ethnic group; pulmonary artery diameter (mm)*								
	Inuit								
	NE		SE,	Inuvik natives		Whites		All groups	
Finding	Normal (15.0)	Abnormal (18.8)	normal (14.4)	Normal (15.2)	Abnormal (18.3)	Normal (13.8)	Abnormal (20.0)	Normal (14.8)	Abnormal (18.7)
	n = 54	n = 33	n = 13	n = 26	n = 10	n = 19	n = 1	n = 112	n = 44
FMF, observed/ expected (%)	94	39	113	102	80	85	50	96	48
Overinflated lungs, no. (and %)	6 (11)	25 (76)	0 (0)	1 (4)	1 (10)	1 (5)	0 (0)	8 (7)	26 (59)
	n = 46	n = 26	n = 9	n = 26	n = 9	n = 19	n = 1	n = 100	n = 36
Axis with standard leads	66°	70°	55°	43°	39°	48°	55°	55°	62°
Transition zone of S/R wave predominance, mean location in chest leads†	4.34	4.60	3.0	3.32	2.72	3.1	4.0	3.7	4.1
Electrocardiographic findings, no. of patients									
Right bundle branch block									
Incomplete	8	13	0	2	1	0	0	10	14
Complete	1	1	0	0	1	2	0	3	2
With left hemiblock	0	4	0	0	0	0	0	0	4
Pseudoinfarction pattern	3	3	0	0	0	0	0	3	3
Left and right ventricular hypertrophy	21	6	0	0	0	0	0	21	6
Ischemia or infarction or both	0	1	0	2	2	2	1	4	4

*Normal range 9 to 16 mm according to Chang.[8]
†For example, the mean location in the white subjects with an abnormal pulmonary artery diameter was the fourth chest lead.

measurements in the men examined in the 1976–78 surveys (Table IV). We found that, in comparison to men with normal pulmonary arteries, men whose pulmonary artery diameters exceeded 17 mm much more often had severely depressed respiratory function (mean FMF, observed/expected 48% v. 96%), roentgenographic evidence of overinflated lungs (59% v. 7%) and right bundle branch block or a pseudoinfarction pattern on ECGs (64% v. 16%).

Other noteworthy findings are depicted in Table IV. The northeastern Arctic Inuit men showed a more vertical axis than the Inuvik natives in standard ECG leads (68° v. 42°) and signs of clockwise rotation in the chest leads: the zone of S/R wave transition was more to the left in the Arctic Bay men than the Inuvik natives, the mean locations in the chest leads being 4.43 and 3.17 respectively. As well, half of the northeastern Arctic Inuit men under 40 years of age had both roentgenographic and electrocardiographic signs of right and left ventricular hypertrophy; this combination of signs was not noted in any of the other groups. On the other hand, electrocardiographic evidence of coronary infarction or ischemic disease of the left ventricle was found in only 1 of 72 northeastern Arctic Inuit but in 4 of 35 Inuvik natives and 3 of 20 white long-term residents of the Arctic.

Table V records the ventilatory function data for the eastern and western Arctic residents grouped according to smoking habits during the last decade. We collected and recorded lifetime smoking histories from all our subjects as best we could. However, we found it impossible to express the data in "pack-years", as most of the Arctic Bay subjects had lived until the mid-1960s in hunting camps where each smoker usually rolled his or her cigarettes from a 200-g tobacco can used by all adolescent and adult members of the extended family; the tobacco content of the self-rolled cigarettes varied greatly. We did, however, collect detailed smoking data between 1953 and 1978 in a number of settlements and trading districts in the Canadian Arctic, including the districts our western and eastern Arctic subjects came from; thus, we can make some general conclusions about the smoking habits of the population groups we studied.

In the mid-1950s the total amount of tobacco used by persons over 15 years old (the age at which practically all natives started to smoke regularly in those days) was 6.6 g/d of tobacco (60% in factory-made cigarettes) for the natives of the Mackenzie delta and 3.1 g/d (less than 10% in factory-made cigarettes) for the residents of the Arctic Bay trading district. Only after the move to settlements in the middle and late 1960s did the Arctic Bay Inuit switch to factory-made cigarettes and increase greatly their total use of tobacco.

Smoking appeared to adversely affect the FMF and the FMF time (FMFT) of all whites, Arctic Bay Inuit aged 25 to 39 years and Inuvik natives aged 25 to 59 years. There was no clear difference in these values between the light and heavy smokers among the youngest natives in both settlements and the men over 60 in Inuvik. Most unexpected, however, was the paradoxic finding that the northeastern Arctic Inuit aged 40 to 80 years who did not smoke or only smoked lightly had the worst ventilatory function. As expected, in most of our groups the heavy smokers had a disproportionately long FMFT. This was even more striking in the group of Inuit miners aged 18 to 45 years working in Nanisivik but coming originally from larger settlements further south; their data are not shown in Table V because of the small numbers in each subgroup. Of these 13 men 10 were heavy smokers; their FMF was nevertheless 13% higher than predicted. Their FMFT, however, was not correspondingly shortened but, instead, 10% longer than the norm.

The high prevalence of tuberculosis in the Inuit[4] has often been blamed for much of their pulmonary impairment.[9] We therefore compared the lung func-

Table V—Relation of smoking to FMF and FMF time (FMFT) in Arctic Bay and Inuvik natives and whites

Age (yr) and average no. of cigarettes smoked per day for last 10 years*	No. of subjects and mean % of expected values†								
	Arctic Bay Inuit			Inuvik natives			Whites		
	No.	FMF	FMFT	No.	FMF	FMFT	No.	FMF	FMFT
16–24									
0-9	9	95	114	3	88	112	2	110	92
10-14	7	119	98	2	140	77	0	–	–
15+	6	92	106	1	141	85	2	82	123
25-39									
0-9	10	99	119	6	121	98	5	99	115
10-14	21	76	154	0	–	–	0	–	–
15+	17	74	153	1	81	138	5	84	154
40-59									
0-9	5	40	227	9	116	93	5	95	114
10-14	6	29	321	1	117	97	0	–	–
15+	9	59	189	10	78	129	2	65	155
60-70+									
0-9	2	18	361	4	66	144	2	61	132
10-14	1	45	177	0	–	–	1	48	126
15+	3	44	211	4	66	134	2	45	192

*For those 16 to 24 years old the average number smoked per day since beginning of regular smoking, at age 14 years in most (period therefore varying from 3 to 10 years).

†Derived from nomogram of Morris and colleagues.[7]

tion, pulmonary artery diameter and electrocardiographic features with the tuberculosis history of our subjects. In general the men who had been hospitalized for tuberculosis had better lung function, smaller pulmonary arteries and less electrocardiographic abnormality than those who had not. This was most apparent in the middle-aged men, but the differences were not statistically significant in any age group.

Discussion

Nomograms used to calculate expected performance in respiratory function tests are height- as well as age-specific. Persons with particularly short legs and relatively large trunks, as are still typical of the Inuit, though more so of those in the eastern than of those in the western Arctic,[4] are compared with controls of equal height but smaller trunks. The FEV_1 and FVC values exceeded those predicted in a group of healthy eastern Arctic Inuit[9] as well as in our northeastern Arctic Inuit men up to 30 years old, southeastern Arctic Inuit men up to 40 years old and western Arctic natives up to 60 years old, but the values would likely have conformed to expectation if the different leg/trunk proportions had been taken into account. Since short stature with characteristically greater reduction of standing than of sitting height is more pronounced in older than in younger Inuit,[10,11] as is also reflected in the heights recorded in Table II, the low respiratory function values recorded for the middle-aged and older men, especially those from the northeastern Arctic, likely underestimate the extent of their respiratory disorder.

The normal FEV_1 and above normal FVC means in the men and the markedly higher percentages of expected for both parameters in the women of an eastern Arctic settlement led to very positive conclusions about the pulmonary function of Inuit.[9] Three other studies[1,5,6] conducted in the eastern Arctic led to different conclusions because of abnormal FMF values, especially in ageing men;[1] abnormalities of the pulmonary arteries and ECGs were also noted.[5,6]

We found marked differences in respiratory function and cardiopulmonary consequences between Inuit men from the northeastern, southeastern and western Arctic (Tables II to IV and Fig. 2). Why should middle-aged but not young and, to a lesser degree, old native men of the northeastern and western Arctic differ so much? While we do not have proof, there is strong circumstantial evidence implicating frequent and lengthy exposure to extremely cold air during hard physical work requiring maximum ventilation and the bypassing of the nasal passages.

Table VI—Average temperatures in 1941—70 in the western Arctic (Aklavik and Tuktoyaktuk)* and in the northeastern Arctic (Arctic Bay)

	Average temperature (°C)			
		Months of most extensive sled travel		
Weather station	Coldest month	March	April	May
Aklavik	January −28.6	−22.3	−12.5	−0.4
Tuktoyaktuk	February −29.2	−24.9	−16.9	−4.6
Arctic Bay	February −31.1	−27.7	−20.4	−7.6

*Aklavik is the geographic and trading centre of the muskrat trappers of the Mackenzie delta. The average temperatures in Inuvik (located also in the Mackenzie delta but 56 km east of Aklavik) were almost identical but were measured for a much shorter period, since the town was established only in the mid-1950s. The temperatures in Tuktoyaktuk, 160 km further north, reflect the conditions along the western Arctic coast to which only the Inuit now over 60 years old and white trappers of Arctic fox were exposed before they moved into the delta 30 to 40 years ago.

Table VI shows isotherms for the coldest month and the months of most extensive sled travel. While differences in absolute temperatures are insignificant for the dead of winter, they are very marked between the Mackenzie delta proper (Aklavik) and the northeastern Arctic in the main travel months, March to May. The values for the western Arctic coast (Tuktoyaktuk) are intermediate.

A large proportion of the present Inuit population of the Mackenzie delta migrated there 30 to 40 years ago from the Arctic coast when the market for fox fur was declining and that for muskrat fur was rising. Muskrat trapping in the delta involved less extensive travelling in the dead of winter and less exposure to storms than had fox trapping along the Arctic coast. Most of the natives in the western Arctic moved some 20 years ago into permanent settlements with more paid employment and little trapping or hunting in the winter, whereas the natives in the northeastern Arctic moved only by the late 1960s into permanent houses, and their winter hunting and trapping in true Arctic surroundings declined much less.

During the last 20 years soapstone carving became a major occupation in certain areas of the Canadian Arctic, particularly the southeastern Arctic but less so in the Arctic Bay area; natives now residing in Inuvik were the least involved. To what extent may inhalation of the dust created in soapstone carving have contributed to the marked impairment of respiratory function and the cardiopulmonary consequences we have described? Four of the five southeastern Arctic Inuit miners (Table III) aged 30 to 39 years said that they had done a good deal of stone carving during the last two decades. Their FMF values exceeded those expected, whereas the FMF values of 27 Arctic Bay hunters of the same age who had done much less stone carving were far below those expected. Stone carving as practised in Arctic Bay does not involve the use of power tools and therefore does not create any significant dust problem.

Excessive smoking was suspected to be the main cause of impaired respiratory function in an earlier study of eastern Arctic Inuit.[1] However, a subsequent study found only moderate cigarette smoking among the men of a larger northeastern Arctic settlement, and this was confirmed by the men's relatively low blood carboxyhemoglobin levels.

Our own data also do not support the earlier claim; in particular, heavy smoking was no more frequent in our northeastern Arctic sample than in our western Arctic sample and, indeed, had been substantially less frequent in the former before their move from hunting camps to settlements in the middle and late 1960s.

The unexpected and paradoxic finding that after age 40 the men in Arctic Bay who were either nonsmokers or light smokers had the worst ventilatory function is so striking that even with due regard for the small numbers it deserves discussion. One possible explanation is that the Arctic residents who have smoked the most and for the longest are the wage-earning employees of government and trading agencies, who have done little or no hunting in winter and have therefore been exposed less to the cold. Also possible is that symptoms or medical admonition caused some older Inuit with chronic bronchitis to stop smoking or cut down.

The depression of the FMF in these men was greater than the corresponding lengthening of the FMFT, reflecting their moderately depressed FVC (Table III). This confirms the clinical observation that patients with typical "Eskimo lung", while predominantly exhibiting features of chronic obstructive lung disease, also often show features of restrictive lung disease.

Our conclusion is at variance with the prevailing notion that inhalation of extremely cold air is unlikely to damage the respiratory tract because the air is sufficiently warmed and humidified as it passes through the complex nasopharynx. This notion is based on experiments in anesthesized dogs alternately inhaling air at room temperature and −35°C, which caused only slight lowering of temperatures in the larynx and trachea.[12] The relevance of these experiments must be questioned, however, in light of the "frosting" of the lungs observed in horses severely exercised in extreme winter conditions in Alaska, the Yukon and northern parts of the Canadian provinces, and the loss of sled dogs showing signs of acute lung edema or more insidiously incapacitated with progressive "short-windedness" after having been driven too hard in extremely cold weather; these observations suggest that during rapid ventilation there are limits to the protection afforded by the nasopharynx, which is certainly more complex and efficient in dogs than in humans.

But more important for us are the recent observations by Russian investigators in northern Siberia natives and immigrant Russian workers engaged for longer periods in hard physical work while exposed to extreme temperatures. These investigators found a high prevalence of pulmonary hypertension[13] and histopathologic changes in the terminal pulmonary arteries and arterioles compatible with an increase in lung vessel resistance;[14] these findings extend our earlier clinical and physiologic observations in Inuit to other circumpolar hunters.

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A word on climate

The Air has an Influence in forming the Languages of Mankind: The serrated close way of Speaking of Northern Nations, may be owing to their Reluctance to open their Mouth wide in cold Air, which must make their Language abound in Consonants; whereas from a contrary Cause, the inhabitants of warmer Climates opening their Mouths, must form a softer Language, abounding in vowels.

—John Arbuthnot (1667–1735),
"An Essay Concerning the
Effects of Air on Human Bodies",
chap. 6, sect. 20