A Population-Based Registry Study of Infant Mortality in the Arctic: Greenland and Denmark, 1973–1997

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Objectives. We sought to determine precise estimates of infant mortality rates and to describe overall trends in infant mortality in Greenland and Denmark from 1973 to 1997.

Methods. We analyzed data from population-based registries of all live-born infants in Greenland and Denmark to calculate infant mortality rates from 1973 to 1997.

Results. Between the periods of 1973–1977 and 1993–1997, neonatal mortality rates in Greenland declined from 20.9 per 1000 live-born infants to 15.7, and postneonatal mortality rates declined from 20.9 per 1000 to 5.9. Infant mortality rates were significantly higher in Greenland than in Denmark, and the excess mortality was uniformly distributed over all birthweight percentiles. In Greenland, the risk of infant death was significantly lower if the mother was born outside Greenland.

Conclusions. Postneonatal mortality rates in Greenland have decreased significantly during the past 25 years, but little progress has been made in decreasing neonatal mortality rates. Disparities exist among children with different maternal origins. (*Am J Public Health.* 2004;94:452–457)

Infant mortality rates are an important measure of a population's health status. Although infant mortality rates in the Arctic have decreased significantly in recent decades, mortality rates remain high as compared with those among populations in the neighboring regions.[1] This is particularly true in Greenland.[2]

The population in Greenland (56 124 in 2000) is primarily composed of indigenous people of Inuit origin (85%–90%) and represents the largest Arctic Inuit population in the world. Greenland has been a colony of Denmark since 1721, but it acquired home rule within the Danish Kingdom in 1979.

There is much cooperation between the health systems of Greenland and Denmark, and the Greenlandic health system is highly dependent on the employment of Danish health personnel. Primarily after World War II, Greenlandic society has undergone rapid improvements in living standards and health sector services.[3] The effect of these social changes and of Westernization in general on infant mortality rates is largely unknown, although previous reports of pronounced regional variation and a high proportion of potentially avoidable deaths indicate that medical progress in infant hospital care has not been satisfactorily implemented.[4]

Previous studies of infant mortality rates in Greenland have primarily used data from death registries, hospital records, or interviews, whereas data on factors such as maternal origin and birthweight have not been generally available.[5–7] To investigate the change in infant mortality rates among Greenlanders compared with Danes, we used population-based national registries in Greenland and Denmark. Our objective was to determine precise estimates of infant mortality rates and to assess the significance of maternal origin and birthweight distribution relative to infant mortality rates in Greenland.

METHODS

We extracted data from the Danish Civil Registration System (CRS), the Medical Birth Registry in Denmark, and the Medical Birth Registry in Greenland. All live-born infants and new residents in Denmark, including Greenland, are recorded in the CRS and are allocated a unique personal identification number (person number). Individual information is recorded according to the person number in all registries; this system of coding enables high-quality linkages between the different registries.

The registration system was established in Denmark on April 1, 1968, and in Greenland on June 1, 1972. It includes information on date of birth, place of birth, gender, and either time of death or date of emigration; vital status data is continuously updated. The register does not contain information on stillbirths. On the basis of this system, we established 2 cohorts and collected data on date and place of birth, vital status, year of birth (1973–1997 in 5-year intervals), gender, maternal age, and birth order for persons born in Denmark and Greenland, including all live-born infants between 1973 and 1997 (n=1 555 439 in Denmark; n=26 014 in Greenland). Additionally, children born in Greenland were categorized according to maternal origin (i.e., mother born in Greenland vs mother born elsewhere). Because of the regional variations in infant mortality rates, children born in Greenland also were divided into 3 categories on the basis of urbanization (municipality size): Nuuk, the capital of Greenland (14 042 inhabitants), towns (>3000 inhabitants), and settlements (≤3000 inhabitants).

We obtained data on birthweight for Danish children from the Medical Birth Registry in Denmark. The registry has data on births to women who reside in Denmark; data were derived from information recorded at birth by midwives, who attend all births in Denmark. Data include birthweight and body length, gender, gestational age, vital status, maternal person number, and, for live-born infants, the child's person number. The only available data on birthweight were for births between 1990 and 1996 to women who were born in Denmark and who were registered with the CRS. This data resulted in a cohort of 414 079 live-born infants.

Data on birthweight for children from Greenland were derived from the Greenland Birth Registry, established in 1989; complete

data were available beginning in 1990. We analyzed only the birthweight of children born between 1990 and 1997 to women who were born in Greenland and who were registered with the CRS. A total of 9098 liveborn infants were registered in the Greenland Birth Registry for 1990-1997. Unlike the Medical Birth Registry in Denmark, the Greenland Birth Registry does not register the person number for a live-born infant. To obtain these numbers, data on date of birth and maternal person number were linked to the CRS, and person numbers were identified for 8938 children (98.2%). Person numbers could not be obtained for the remaining 160 children, possibly owing to adoption, misclassification of vital status, and erroneous registration. Limiting the subanalysis of the influence of birthweight to infants born to mothers from Greenland resulted in a cohort of 8174 live-born infants (96.9%).

We calculated neonatal, postneonatal, and total infant mortality rates by dividing the number of deaths occurring less than 28 days after birth, 28 to 365 days after birth, or 0 to 365 days after birth (nominators) by the number of all live births (denominator). Estimates of postneonatal rates did not change when infants who died during the neonatal period were removed from the denominator.

We estimated relative neonatal and postneonatal mortality rates with log-linear binomial regression adjusted for year of birth by 5-year period, maternal age, gender, birth order, and, for children born in Greenland, degree of urbanization of place of birth. Rates and relative risks of mortality were calculated for children born in Greenland to mothers who were born in Greenland and for all children born in Denmark. The group of children born in Greenland to mothers who were born outside Greenland was analyzed separately.

We obtained infant mortality rates for all of Canada and for the Northwest Territories of Canada from Statistics Canada.[1,8] Infant mortality rates for all of Alaska and for Alaska Natives, which includes both Inuit and Native Americans, were obtained from the State of Alaska Department of Health and Social Services. The rates were only available as 3-year moving averages (from the year in question and the 2 preceding years).[9]

TABLE 1—Distribution of Live-Born Infants, by Maternal Origin: Greenland and Denmark, 1973–1997

	Greenland, No. (%)		
	Mother Born in Greenland	Mother Born Outside Greenland	Denmark, No. (%)
Total no. of live-born infants	23 136	2878	1 555 439
Year of birth			
1973–1977	3543 (15.3)	790 (27.4)	342 422 (22.0)
1978–1982	4268 (18.4)	575 (20.0)	284 905 (18.3)
1983–1987	4697 (20.3)	545 (18.9)	268 412 (17.3)
1988–1992	5531 (23.9)	502 (17.4)	316 320 (20.3)
1993–1997	5097 (22.0)	466 (16.2)	343 380 (22.1)
Maternal age, y			
12–19	3975 (17.2)	118 (4.1)	61 984 (4.0)
20–24	7656 (33.1)	543 (18.9)	406 421 (26.1)
25–29	6304 (27.2)	1174 (40.8)	610 454 (39.2)
30–34	3493 (15.1)	749 (26.0)	353 536 (22.7)
≥ 35	1708 (7.4)	294 (10.2)	123 044 (7.9)
Gender			
Male	11 812 (51.1)	1471 (51.1)	798 751 (51.4)
Female	11 324 (48.9)	1407 (48.9)	756 688 (48.6)
Birth order			
1	8681 (37.5)	1199 (41.7)	699 685 (45.0)
2	6394 (27.6)	991 (34.4)	577 178 (37.1)
3	3933 (17.0)	509 (17.7)	207 848 (13.4)
≥ 4	4128 (17.8)	179 (6.2)	70 728 (4.5)
Urbanization (Greenland only)			
Nuuk (capital)	4315 (18.7)	1298 (45.1)	. . . (. . .)
Towns	9265 (40.0)	915 (31.8)	. . . (. . .)
Villages	9556 (41.3)	665 (23.1)	. . . (. . .)
No. of infant deaths	707 (3.1)	33 (1.1)	12 349 (0.8)

RESULTS

Table 1 shows the distribution of live-born infants in Greenland and Denmark by year of birth (1973–1997 in 5-year intervals), maternal age, gender, birth order, urbanization (Greenland only), and maternal origin (Greenland only). Approximately 89% of all births in Greenland were to mothers born in Greenland. The mean maternal age at birth of the first child in 1973 was 20.5 years in Greenland and 23.7 years in Denmark; in 1997 the mean maternal ages were 24.0 years and 27.1 years, respectively.

From January 1973 to December 1997, we recorded 707 infant deaths in Greenland: 413 (58.4%) occurred during the neonatal period, and 294 (41.6%) occurred during the postneonatal period. During this 25-year interval in Denmark, a total of 12 349 infant deaths were recorded: 8305 (67.3%) were neonatal deaths, and 4044 (32.7%) were postneonatal deaths.

Birthweight data are shown in Table 2. In Greenland, gestational age was registered for 7584 (92.8%) births. The mean gestational age was 39.2 weeks (SD=2.0 weeks), and 6.9% were born before 37 weeks. In Denmark, gestational age was registered for 410 431 (99.1%) births. The mean gestational age was 39.5 weeks (SD=2.0 weeks), and 5.7% were born before 37 weeks.

The crude infant mortality rate in Greenland decreased from 46 per 1000 live-born infants in 1973 to 23 per 1000 live-born infants in 1997. During the same period, the crude infant mortality rate in Denmark decreased from 9 per 1000 live-born infants to

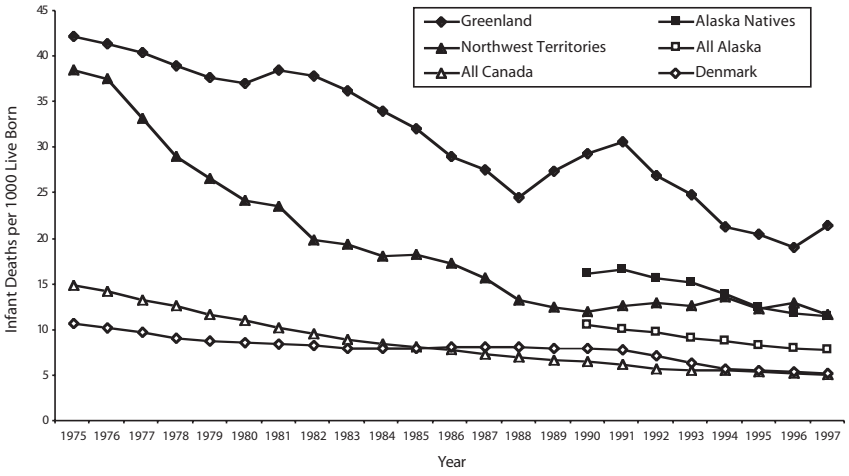

FIGURE 1—Infant mortality rates in the Arctic regions of North America, 1975–1997.

TABLE 2—Birthweight Distributions (%) and Mean Birthweights With Standard Deviations: Greenland (1990–1997) and Denmark (1990–1996)

Birthweight, g	Greenland[a] (n = 8174), %	Denmark[b] (n = 414 079), %
≤ 1499	1.9	1.9
1500–2499	3.4	3.2
2500–2999	12.6	11.7
3000–3499	32.4	31.8
3500–3999	32.2	33.4
4000–4499	14.0	14.6
≥ 4500	3.5	3.3
Birthweight, mean (SD)	3444g (602 g)	3468 g (596 g)

[a]Mothers born in Greenland.
[b]Mothers born in Denmark.

6 per 1000 live-born infants. A small percentage of children in Greenland (1.8%) and Denmark (2.7%) were registered as having disappeared or emigrated before the age of 1 year; however, removing these children from the denominator had no overall effect on the mortality rate estimates.

Between 1975 and 1997, an overall decrease in the infant mortality rate in Greenland occurred, but an increase occurred between 1989 and 1992 (Figure 1). The infant mortality rates for, respectively, Alaska Natives, populations of the Northwest Territories of Canada, and Greenland were considerably higher than those for all of Alaska, all of Canada, and Denmark.[1,8,9] Additionally, infant mortality rates were exceptionally high in Greenland and are now almost twice as high as infant mortality rates both among populations in the Northwest Territories and among Alaska Natives.

As shown in Table 3, neonatal and postneonatal mortality rates (stratified by year of birth, maternal age, gender, and birth order) are generally higher in Greenland than in Denmark. In Greenland, the relative decline in neonatal mortality rates over time has been limited. The neonatal mortality rate is positively associated with increasing birth order and inversely associated with maternal age. In Denmark, we observed no clear trend among birth order, maternal age, and neonatal mortality rates.

Adjusted postneonatal mortality rates in Greenland decreased 70% between the 5-year periods of 1973–1977 and 1993–1997, whereas postneonatal mortality rates in Denmark only decreased after 1992. Postneonatal mortality rates in both Greenland and Denmark were strongly and positively associated with increasing birth order and were inversely associated with maternal age.

There was a marked regional variation in infant mortality rates in Greenland, with the lowest mortality rates observed in Nuuk and the highest mortality rates observed in the settlements. The neonatal mortality rates in Nuuk, the towns, and the settlements were 13.0, 16.5, and 21.3 per 1000 live-born infants, respectively. Compared with Nuuk, these mortality rates correspond to adjusted relative risks of 1.2 for towns and 1.6 for settlements. Likewise, the postneonatal mortality rates in Nuuk, the towns, and the settlements were 6.7, 12.4, and 15.7 per 1000 live-born infants, respectively, which corresponds to adjusted relative risks of 1.6 for towns and 1.9 for settlements.

A total of 2878 (11.1%) births were registered as in the category of children born in Greenland to mothers who were born outside Greenland (primarily in Denmark) (91%). The neonatal and postneonatal mortality rates for this group were 7.3 and 4.2 per 1000 live-born infants, respectively. The neonatal and postneonatal mortality rates for children born to mothers who were born in Greenland were 17.9 and 12.7 per 1000 live-born infants, respectively. After adjustment for year of birth (in 5-year groups), maternal age, gender, birth order, and urbanization of birth location, these rates correspond to relative risks of 1.9 (95% confidence interval [CI]=1.2, 2.9) for neonatal mortality and 2.3 (95% CI=1.3, 4.2) for postneonatal mortality in children born to mothers who were born in Greenland.

Figure 2 shows infant mortality rates for children born in Greenland and Denmark for each 10-percent weight-percentile, which ensures an even distribution of births for each group along the X-axis. Thus, each point on each line represents the same proportion of

TABLE 3—Neonatal and Postneonatal Mortality Rates (Deaths per 1000 Live-Born Infants): Greenland and Denmark, 1973–1997

	Neonatal Mortality Rates						Postneonatal Mortality Rates					
	Greenland[a]			Denmark			Greenland[a]			Denmark		
	NMR	RR[b]	95% CI	NMR	RR[c]	95% CI	PMR	RR[b]	95% CI	PMR	RR[c]	95% CI
Year of birth												
1973–1977	20.9	1	Ref	7.6	1	Ref	20.9	1	Ref	2.7	1	Ref
1978–1982	19.9	1.0	0.7, 1.3	5.5	0.7	0.7, 0.8	17.8	0.9	0.6, 1.2	3.0	1.2	1.1, 1.3
1983–1987	17.2	0.9	0.6, 1.2	5.0	0.7	0.6, 0.7	12.1	0.6	0.4, 0.9	3.2	1.3	1.2, 1.4
1988–1992	16.8	0.9	0.6, 1.2	4.6	0.6	0.6, 0.7	10.3	0.5	0.4, 0.8	2.9	1.2	1.1, 1.3
1993–1997	15.7	0.8	0.6, 1.1	4.0	0.5	0.5, 0.6	5.9	0.3	0.2, 0.5	1.5	0.6	0.6, 0.7
Maternal age, y												
12–19	20.6	1.5	1.1, 2.1	8.1	1.4	1.3, 1.6	14.3	1.9	1.2, 2.9	5.3	3.0	2.7, 3.4
20–24	18.7	1.2	0.9, 1.5	5.8	1.1	1.0, 1.2	12.9	1.4	1.0, 1.9	3.2	1.6	1.5, 1.7
25–29	18.6	1	Ref	4.8	1	Ref	11.9	1	Ref	2.2	1	Ref
30–34	13.7	0.7	0.5, 0.9	5.0	1.1	1.0, 1.2	12.0	0.9	0.6, 1.3	2.2	0.8	0.8, 0.9
≥35	13.5	0.6	0.4, 0.9	5.9	1.3	1.2, 1.4	12.3	0.7	0.4, 1.2	2.3	0.8	0.7, 0.9
Gender												
Male	19.1	1.0	Ref	6.1	1	Ref	14.5	1	Ref	2.9	1	Ref
Female	16.5	0.9	0.7, 1.1	4.6	0.8	0.7, 0.8	10.9	0.8	0.6, 1.0	2.2	0.8	0.7, 0.8
Birth order												
1	16.4	1	Ref	5.7	1	Ref	9.9	1	Ref	2.3	1	Ref
2	17.4	1.3	1.0, 1.6	4.7	0.8	0.8, 0.9	11.6	1.5	1.1, 2.2	2.7	1.5	1.4, 1.7
3	17.8	1.4	1.0, 2.0	5.2	0.9	0.9, 1.0	14.5	2.2	1.5, 3.3	2.9	2.0	1.8, 2.2
≥4	21.8	2.0	1.4, 2.9	7.1	1.2	1.1, 1.3	18.7	3.0	2.0, 4.6	3.9	2.8	2.5, 3.3

Note. NMR = neonatal mortality rate; PMR = postneonatal mortality rate; RR = relative risk; CI = confidence interval; Ref = reference group.
[a]Mothers born in Greenland.
[b]Relative risk adjusted for year of birth, maternal age, gender, birth order, and urbanization.
[c]Relative risk adjusted for year of birth, maternal age, gender, and birth order.

births in Greenland and Denmark. Figure 2 shows that infant mortality rates were consistently higher for children born in Greenland, except for those in the highest birthweight percentiles.

DISCUSSION

During the early 1960s, when data on infant mortality rates in the Arctic regions became available, mortality rates for Greenland were significantly lower than for Northwest Territory Inuit and similar to rates for Alaska Natives.[10] Despite a steady decline in Greenland, infant mortality rates in Greenland are now the highest in the Arctic regions of North America.

The presence of complete national registers in both Greenland and Denmark enabled us to investigate infant mortality rates with a nationwide cohort design that controlled for confounders such as maternal age, birth order, and maternal origin. Such an approach has not previously been used for populations of Arctic regions. Furthermore, using the CRS as a single data source for identification of live-born infants offers advantages compared with previous studies of infant mortality rates in Greenland, which used data from a combination of different registries.[4]

Ethnic affiliation could not be ascertained for our study; therefore, children born in Greenland were divided into 2 groups, on the basis of maternal origin. Approximately 10% of all births were to mothers who were born outside Greenland, primarily in Denmark. Danes who live in Greenland are mainly transient residents who possess a different set of socioeconomic characteristics than do the native populations.[10] For this reason, we separately analyzed infant mortality rates for Greenlanders and Danes living in Greenland.

When one compares infant mortality rates among populations in the Arctic regions, certain differences must be taken into account. Infant mortality rates for the Northwest Territories of Canada are available for all ethnic groups combined, but data specifically on the Inuit were not available.[1,8] However, in the Northwest Territories, native peoples make up approximately 62% of the total population. In Alaska, data are available both for native peoples and for the population in general.[9] When we compared infant mortality rates in Greenland with those in the other regions we restricted our analysis to Greenland rates for children whose mothers were born in Greenland. However, inclusion of all children born in Greenland (i.e., regardless of mothers' place of birth) did not change the overall infant mortality rates in Greenland, which were still well above the rates in other Arctic regions.

The absolute differences in neonatal and postneonatal mortality rates between Denmark and Greenland may partly be explained by differences in access to advanced technology and health care services. Highly specialized neonatal care cannot be expected at all times in a small and scattered population, and even in countries with a generally high standard of infant care, perinatal mortality rates have been found to be inversely associated with population density and with annual number of births.[11]

However, of more concern is the fact that medical and technological developments of the past 25 years have not resulted in a larger decrease in neonatal mortality rates in Greenland. The rates in Greenland decreased approximately 20%, while rates decreased in Denmark by 50% during the same period. This difference could indicate insufficient implementation of medical improvements. A contributing, although smaller, factor is probably smoking habits, especially among young women in Greenland. During the past 25 years, the total cigarette consumption in Greenland has been extraordinarily high; in 1996 two thirds of women who gave birth in Greenland were smokers.[12] By comparison, one third of women in Denmark smoked during pregnancy in 1996.[13] Smoking during

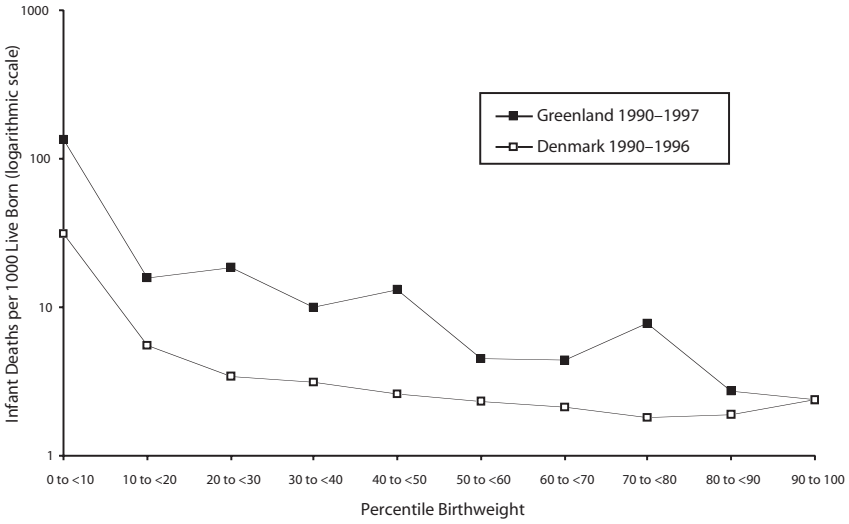

FIGURE 2—Infant mortality rates in Greenland and Denmark, 1990–1997.

pregnancy almost doubles the risk of infant death, conferring an increased risk of preterm birth,[14,15] and the high prevalence of smoking in the Arctic area has been found to be associated with high rates of infant mortality.[16]

In contrast to the limited decrease in neonatal mortality rates, the decrease in postneonatal mortality rates in Greenland is outstanding. In the 1970s, postneonatal mortality rates equalled neonatal mortality rates; current postneonatal mortality rates have dropped to a level equal to one third of current neonatal mortality rates. The same trend is seen internationally, but not at the rate seen in Greenland.[17] Postneonatal mortality rates are strongly associated with socioeconomic differences,[18] and the marked decrease in postneonatal mortality rates in Greenland parallels the rapid socioeconomic development over the same period, when average incomes, degree of urbanization, and housing standards all have increased.[10,19,20] The prevalence of breastfeeding for 3 months or more in Greenland increased from 62% in the 1960s to 75% in the 1990s[10] and is now equivalent to the prevalence in Denmark.[21]

A comparison of causes of infant death in Greenland and Denmark between 1970 and 1989 reveals that infants in Greenland had a substantially higher risk of dying from infectious diseases and accidents.[4] Meningitis, measles, and diarrhea were found to be frequent causes of death; however, more recent data from 1992 to 1999 indicate that the proportion of infant deaths due to infectious diseases in Greenland is declining.[22] This observation is consistent with a decrease in postneonatal mortality rates.

The standard vaccination program in Greenland follows that of Denmark. Previous studies have shown that coverage rates for these vaccines are high; these rates are equal to or higher than the levels of Western countries.[23] Thus, it is unlikely that the present difference in postneonatal mortality between Greenland and Denmark can be explained by differences in vaccine coverage.

In Greenland, neonatal mortality rates decrease as maternal age increases, whereas neonatal mortality rates in Denmark increase as the maternal age exceeds 30 years. The increased mortality rates in Denmark may partly be explained by the use of in vitro fertilization, which increases the risk of multiple births and, consequently, the risk of infant death.[24] In vitro fertilization is most likely seldom used in Greenland.

The maternal age at birth of the first child is higher in Denmark than in Greenland, and an almost parallel increase in maternal age in the 2 countries was observed between 1973 and 1997. The age difference alone could potentially explain part of the difference in neonatal and postneonatal mortality rates between Greenland and Denmark. However, the difference in mortality between Greenland and Denmark is maintained within the different age strata; therefore, confounding by maternal age is unlikely.

Increased infant mortality rates associated with increasing birth order have been observed in other surveys[25] and may be attributable to confounding by socioeconomic factors, for which we were unable to adequately adjust in our study. In Denmark, neonatal mortality rates showed modest variation relative to birth order, whereas in Greenland neonatal mortality rates increased steadily with birth order. Assuming that the association is confounded by socioeconomic factors, one could speculate that the high level of specialized neonatal care in Denmark reduces the effects of socioeconomic factors, whereas the overall lower level of neonatal care in Greenland allows these effects to be more visible.

Infant mortality rates in the subgroup of children born in Greenland to women who were born outside Greenland were found to be significantly lower than the mortality rates in other children born in Greenland. Direct comparison of the 2 groups of children is difficult because of the different distribution of socioeconomic factors. However, the low infant mortality rates in the subgroup of children born to primarily Danish mothers indicate that a lower infant mortality rate in Greenland is an obtainable goal.

Data on birthweights in Greenland were available only for 1990 to 1997. The birthweight distribution did not differ markedly between the 2 countries, and in both Greenland and Denmark, 1.9% of infants had a birthweight below 1500 grams. Using a percentile-based method of standardization,[26] we found that the excess mortality among Greenlanders compared with that of Danes is spread out over the whole birthweight distribution and is, therefore, not primarily caused by a higher number of small births. This finding is important, because it illustrates that the high mortality rates in Greenland are caused by factors that affect not only the small, low-weight children but all of the children born in the country.

Birthweight alone as a measure has limitations, because infants born within the lower normal range can be as "growth retarded," compared with their unaffected weight, as low-weight babies. The proportion of premature births (<37 weeks) is only slightly larger in Greenland than in Denmark. However, data on gestational age in Greenland are missing for 7.2% of all births (compared with 0.9% of births in Denmark), and the determination of gestational age may vary considerably within Greenland, because ultrasound scanning is not used to the same extent in all districts.

Our study demonstrates that postneonatal mortality rates in Greenland have decreased significantly over the past 25 years, while little progress in lowering neonatal mortality rates has occurred. Significant differences between Denmark and Greenland persist, and Greenland now has the highest infant mortality rate in the Arctic region. A top priority in the years to come is to maintain the trend toward decreasing infant mortality rates by focusing on mortality during the neonatal period. In this regard, ongoing evaluations of infant mortality and health sector standards are crucial. ■

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Contributors

J. Friborg, A. Koch, J. Wohlfarht, and M. Melbye conceived of and designed the study and analyzed and interpreted the data. J. Friborg drafted the article, and all of the authors reviewed the article for intellectual content. J. Wohlfarht provided statistical expertise, A. Koch and M. Melbye obtained funding, and F. Stenz provided administrative and technological support. A. Koch, F. Stenz, and M. Melbye supervised the study.

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Human Participant Protection

As it was a registry study, no ethical protocol approval was needed for the study.

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