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A population-based register study of vaccine coverage among children in Greenland

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Abstract

To assess coverage rates of standard childhood vaccinations in Greenland, a geographically isolated and sparsely populated area, and to determine risk factors for low coverage, we performed a register-based cohort study among 596 children from 1993 to 1998 in Sisimiut, Greenland. For vaccines given before the age of 2 years (pertussis 1–3, DT-IPV 1–3, and MMR 1) coverage rates in general were impressively high being on or above levels of Western countries. A risk factor for low coverage was migration. The Greenlandic vaccination model with free vaccinations administered by health workers who systematically call in children at scheduled times seems highly efficient and could be a model for other similar countries.

Keywords: Vaccine coverage; Childhood; Greenland

1. Introduction

In the past, the Greenlandic population has experienced severe and devastating epidemics of vaccine-preventable disorders, in particular of measles, tuberculosis, and polio [1]. As a part of the Danish kingdom the standard childhood vaccination programme in Greenland introduced in recent decades follows that of Denmark [2,3] with all vaccinations administered free of charge. The vaccinations dispense system in Greenland outside the capital Nuuk is, however, different from that of Denmark, as children are vaccinated by health visitors and not by doctors.

Vaccine coverage rates among children in Greenland and risk factors associated with not receiving planned vaccinations are unknown. To gain insight into these issues we conducted a study of vaccine coverage among children in the town of Sisimiut, the second biggest town of Greenland, and two adjacent settlements with the objectives to estimate vaccine coverage among children, to evaluate the delay in vaccination, and to determine risk factors associated with not receiving the vaccinations.

2. Materials and methods

2.1. Study area and population

The population of Greenland is sparse (55,000 of whom 15,000 live in the capital Nuuk) and lives scattered around the island in 16 towns and a large number of settlements. Medical doctors serve most towns, while doctors only visit the settlements at irregular intervals.

The study area was the West Greenlandic town of Sisimiut and two adjacent settlements, Sarfannguaq and Itilleq, together constituting Sisimiut municipality (in the following unless explicitly stated as ‘Sisimiut town’, ‘Sisimiut’ alone denotes Sisimiut municipality). Approximately 5100 persons live in Sisimiut town, hereof approximately 600 born outside Greenland, mainly in Denmark. In total 240 persons live in the two settlements, divided equally among the two. One Health Centre with up to five doctors at a time serves the whole town and functions both as outpatient clinic and in-patient hospital, while the doctors only irregularly visit the settlements.

In Sisimiut town health visitors administer childhood vaccinations weekly at the Health Centre. At relevant ages children living in the town are called to the Health Centre to receive their vaccinations. If the children do not turn up at the scheduled day, they receive a written reminder. In the two settlements, the health visitors of Sisimiut town

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administer childhood vaccinations less regularly at the local nursing station, when they visit the settlements every month or every second. Children are at relevant ages called to the nursing station, and if they do not show up, an effort is made to vaccinate the children at the subsequent visit.

The study population was an open cohort consisting of all children born between 1 April 1993 and 8 August 1997, and living in Sisimiut at a time between 1 April 1993 and 10 November 1998. Thus, both children born in Sisimiut and children moving into Sisimiut were included. Only children being adopted out of Sisimiut shortly after birth were excluded. The children were identified through the Civil Registration System. Children were followed prospectively from time of birth till 10 November 1998, till they moved out of Sisimiut, or till death, whichever came first. Information on time living in Sisimiut was obtained through the Civil Registration System that includes such information as time of birth, death, emigration, immigration, etc. All reporting to this registry takes place less than a week after the event.

2.2. Standard vaccination programme

The standard childhood vaccination programme in Greenland follows that of Denmark (Table 1). *Haemophilus influenzae* type b (Hib) vaccination was introduced in Greenland in 1996. This vaccination was given very irregularly in the beginning and is therefore excluded from this material.

2.3. Vaccine and background information

Information on vaccinations given in the study period was obtained from vaccination files kept by the health visitors at the Health Centre, in which all vaccinations administered to children in Sisimiut and the two settlements are recorded. Information on gender, birth order, place of birth and living, ethnicity according to parents' place of birth, and parents' age at child's birth was obtained through the Civil Registration System. Information on birth variables was obtained through the Greenlandic Birth Registry, a mandatory reportable register kept by the Chief Medical Officer of Greenland.

Table 1
Standard childhood vaccination programme per 1 April 1993, in Sisimiut, Greenland

Age	Vaccination
5 weeks	Pertussis 1
9 weeks	Pertussis 2
5 months	Diphtheria, tetanus, polio (DT-IPV[a]) 1
6 months	Diphtheria, tetanus, polio (DT-IPV[a]) 2
10 months	Pertussis 3
15 months	Diphtheria, tetanus, polio (DT-IPV[a]) 3 + measles, mumps, rubella (MMR[a]) 1
2 years	Oral polio (OPV) 1
3 years	Oral polio (OPV) 2
4 years	Oral polio (OPV) 3
12 years	Measles, mumps, rubella (MMR[a]) 2

[a] Compound vaccines.

For a subset of children that took part in a study of respiratory tract infections from 1 April 1996 to 7 December 1998, information on passive smoking, social factors, and episodes of respiratory tract infections was obtained [4]. These children were all below 2 years of age, living in Sisimiut town between August 1996 and August 1998, and monitored weekly for respiratory tract infections. Social class of individuals was defined according to the Danish Social Classification System [5]. Episodes of respiratory tract infections as a proxy measure for general health were recorded on a weekly basis based on symptoms reported by parents, and prevalence of respiratory tract infections was defined as days with reported symptoms divided by total days of observation.

2.4. Coverage rates and statistics

The vaccination coverage rates were determined as (1) coverage rate for each of the nine vaccinations up to the age of 4 years, and as (2) coverage rate at age 2 years for all planned vaccinations until this age. For all analyses Kaplan–Meier estimates were used. For each of the specific vaccines coverage rates were estimated using a Kaplan–Meier estimate of the probability of having received the relevant vaccination at 1 month and 1 year after the scheduled time, respectively. Only children living in the area on the official vaccination date were included in the estimation. Each child contributed with time from birth or immigration to the area, whatever came latest, until the vaccination of interest was received, until 10 November 1998, until a new vaccination programme was started, until death, or until emigration out of the area, whichever came first. Coverage rate at 2 years of age was estimated using a Kaplan–Meier estimate of the probability of having received all scheduled vaccinations at that age. Only children born in Sisimiut were used in the estimation. Each child contributed with time from birth until all scheduled vaccinations up to DT-IPV 3 + MMR 1 were received, until 10 November 1998, until a new vaccination programme was started, until death, or until emigration out of the area, whichever came first.

To test whether the vaccine coverage rates of children moving into Sisimiut would affect the overall estimate of coverage rate at age 2 years, two additional Kaplan–Meier analyses were performed. In the first analysis all children who had lived in the area at any point of time during the first 2 years of life, whether or not born in the area, were included. In the other analysis only children who had not lived in the area for the full 2 years of life were included. The additional analyses were carried out as described above, with each child contributing with the time spent in Sisimiut before age 2 years.

Differences in vaccination coverage at age 2 years according to different risk factors were statistically evaluated

by assuming that the logarithm of the coverage is normally distributed. Risk factors included the child's place of living (town/settlement), gender, ethnicity (Greenlandic, mixed or Caucasian), birth order, weight at birth, social class, time spent with acute respiratory tract infections (more or less than the average), mother's and father's ages at child's birth, mother's alcohol consumption, smoking, schooling, education, and smoking in the household. All risk factors, except for 'place of living', were treated as constant variables based on information obtained for time of birth or inclusion in the study. Place of living was treated as a time-dependent variable, i.e. each child contributed at a given time with information on this variable during follow up depending on place of living at that time.

Kaplan–Meier estimates, standard errors, 95% confidence interval (CI), and *P*-values were calculated using the procedure PROC PHREG in SAS.

2.5. Ethics

The Commission for Scientific Research in Greenland that acts as scientific ethical board in Greenland approved the study. According to Danish law the study was also reported to the Danish Data Protection Board.

3. Results

3.1. Study population

In total 596 children participated in the cohort study contributing with 1515 years of observation (on average 2.5 years of observation per child). Table 2 presents the demographic characteristics of the cohort and age distribution of time at risk. None of the children in the study died.

3.2. Coverage rates for specific vaccines

Table 3 shows the vaccine coverage for specific vaccines. There is a clear tendency towards a decreasing coverage rate from early to late vaccines, evaluated 1 month after the scheduled vaccination date and again after 1 year. In particular, coverage rates for vaccines administered after the age of 2 years were substantially lower than the earliest vaccines. Over 90% of the children were vaccinated at the scheduled time with pertussis 1, but fewer than 50% of the children were vaccinated at the scheduled time with OPV 3.

To test whether the coverage rates for specific vaccines were dependent upon the definition of the actual study population as children residing in Sisimiut at the age of planned vaccination, we determined coverage rates using children resident in Sisimiut both 14 days before and after the given vaccination age, as well as children resident only at any point of time during this period. No differences in vaccine coverage rates were found using these definitions compared with the original definition.

Table 2
Demographic characteristics of study cohort of 596 children living in Sisimiut, Greenland, 1993–1998

	Children born in Sisimiut $N = 453$	Children born outside Sisimiut $N = 143$
Gender		
Boys	223 (49.2)	80 (55.9)
Girls	230 (50.8)	63 (44.1)
Place of living		
Sisimiut town	415 (91.6)	143 (100)
Settlement	38 (8.4)	0 (0)
Ethnicity		
Greenlandic	385 (85.0)	105 (73.4)
Mixed/Caucasian	68 (15.0)	38 (26.6)
Mother's age at child's birth		
<20 years	44 (9.7)	15 (10.5)
≥20 years	409 (90.3)	128 (89.5)
Father's age at child's birth		
<20 years	61 (13.5)	19 (13.3)
≥20 years	392 (86.5)	124 (86.7)
Birth order		
First born	130 (28.7)	43 (30.1)
Later born	323 (71.3)	100 (69.9)
Time at risk[a]		
0–1 years old	417 (31)	36 (21)
1–2 years old	364 (27)	51 (30)
2–3 years old	261 (19)	50 (29)
3–4 years old	189 (14)	25 (15)
4–5 years old	101 (8)	6 (4)
5–6 years old	11 (1)	3 (2)

Percentage values are indicated within parentheses.
[a] The number of years at risk in each stratum.

3.3. Vaccine coverage at 2 years of age

As the number of children older than 2 years in the cohort is limited, we chose to evaluate general vaccine coverage at the age of 2 years instead of after the full vaccination series of 4 years. The coverage rate for the scheduled seven vaccinations (pertussis 1–3, DT-IPV 1–3 and MMR 1) at 2 years of age among the 453 children who had lived in Sisimiut from birth was 92.6% (95% CI 90.0–95.2). The additional Kaplan–Meier analyses (Fig. 1) showed that 87.8% (95% CI 84.7–90.9) of the total number of children who had lived in Sisimiut at any point of time before the age of 2 years ($n = 466$), whether or not born in Sisimiut, had received their scheduled vaccinations at age 2 years, while the rate for children who had moved into Sisimiut after birth was significantly lower at 53.2% (95% CI 40.5–65.8, $P < 0.001$).

3.4. Risk factors for low coverage at 2 years of age

Four hundred and fifty-three out of 596 children (76%) were born in Sisimiut and formed the basic study population for risk factor analyses. Vaccine coverage differed markedly between children who had lived in Sisimiut since

Table 3
Vaccine coverage for specific vaccines for the cohort of 596 children living in Sisimiut, Greenland, 1993–1998

Vaccination	Vaccine coverage in percent (95% CI[a]) by time since standard recommendation					
	Children born in Sisimiut municipality			Children born outside Sisimiut municipality		
	Children available for vaccination[b]	Vaccine coverage after 1 month	Vaccine coverage after 1 year	Children available for vaccination[b]	Vaccine coverage after 1 month	Vaccine coverage after 1 year
Pertussis 1	443	91.3 (88.8–93.9)	97.9 (96.5–99.2)	9	88.9 (74.4–100)	100 (100–100)
Pertussis 2	439	81.2 (77.5–84.9)	96.7 (94.8–98.6)	9	88.9 (74.4–100)	100 (100–100)
DT-IPV 1	421	84.9 (81.5–88.2)	97.9 (96.4–99.3)	20	67.0 (47.0–87.0)	85.3 (70.0–100)
DT-IPV 2	418	69.7 (65.3–74.1)	97.6 (96.1–99.1)	20	61.8 (41.0–82.6)	89.1 (77.4–100)
Pertussis 3	411	75.4 (71.3–79.5)	94.9 (92.6–97.2)	28	45.0 (25.7–64.4)	74.3 (52.6–96.0)
DT-IPV 3 and MMR 1	403	70.6 (66.3–75.0)	94.8 (92.2–97.5)	37	47.7 (31.0–64.4)	67.4 (48.8–85.9)
Oral polio 1	318	69.7 (64.7–74.2)	90.7 (86.4–95.1)	41	32.8 (18.3–47.3)	70.2 (51.8–88.7)
Oral polio 2	228	56.4 (50.0–62.9)	86.4 (80.7–92.1)	41	30.7 (16.5–44.9)	58.1 (36.0–80.3)
Oral polio 3	138	48.6 (40.1–57.1)	82.3 (74.3–90.5)	24	29.6 (11.4–47.8)	40.5 (19.0–61.9)

All values for vaccine coverage after 1 month and 1 year are expressed in percentage.
[a] Confidence interval.
[b] Only children residing in Sisimiut at the age of planned vaccination.

birth and immigrants, but the group of immigrants was too small for risk factor analyses. Of the 453 children born in Sisimiut 226 children took part in the study of respiratory tract infections and supplied information on social factors, passive smoking, etc. Significant risk factors ($P < 0.05$) were ethnicity (coverage for Greenlandic children 91.7% (95% CI 88.6–94.7%), for children of mixed/Caucasian descent 98.2% (95% CI 95.7–100%)), smoking in household (coverage for children from households with smokers 89.8% (95% CI 85.5–94.2%), and for children from smoking free households 96.8% (95% CI 92.4–100%)). For children, who had had respiratory tract infections of less than the average (23% of time of observation) coverage rate was 85.9% (95% CI 79.5–92.3%), and for children with respiratory tract infections of more than the average coverage rate was 95.7% (95% CI 92.1–99.4%). For children of young mothers and fathers, for children whose mothers smoked, for children whose mothers had low school education, and for children with low birth weights coverage rates tended to be lower, however, insignificant. As place of living (town/settlement) was not a risk factor, we analysed whether the vaccines were given with delay in the settlements. Fig. 1 shows that this was the case, but that the same coverage was reached at the age of two for the two groups of children.

3.5. Confounding

Survival analysis was performed instead of logistic regression, as only about 60% of the children were followed for 2 years or more after birth. There is no standard method

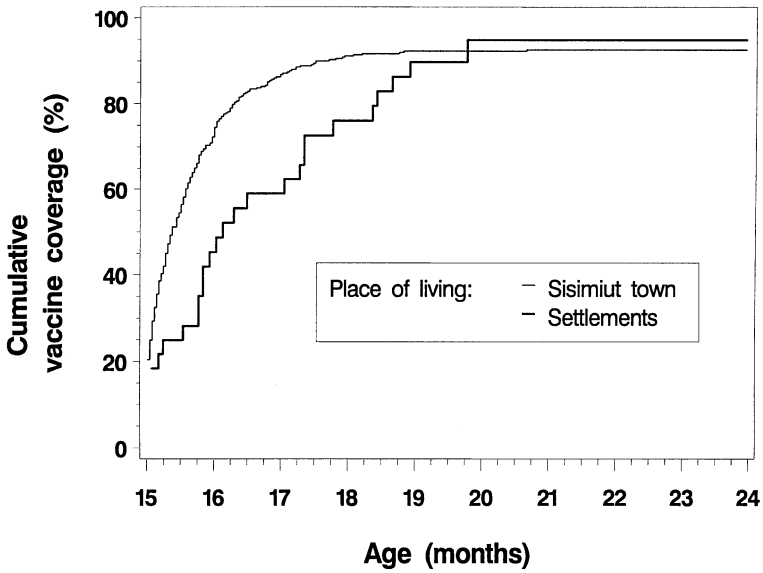

Fig. 1. Cumulative vaccine coverage for the first seven vaccines (pertussis 1–3, DT-IPV 1–3 and MMR 1) for 425 children living in Sisimiut town and 41 children living in one of the settlements from the official vaccination age of the seventh vaccine (15 months) to 2 years of age, irrespectively of place of birth.

for multivariate regression analyses of Kaplan–Meier point estimates, and stratified analyses could not be performed due to a low number of non-vaccinated children in combined strata. Thus, it was not possible to test confounding between the three significant factors (ethnicity, smokers in household (or mother's smoking), and the presence of respiratory tract infections) using a stratified analysis. However, the three factors were not correlated and they are unlikely to be confounders.

4. Discussion

This is, to our knowledge, the first study of coverage rates of common childhood vaccinations among children living in the Arctic. To obtain as valid information as possible of vaccinations and time at risk in Sisimiut, we took advantage of two registers, the vaccination register kept by the health visitors performing the vaccinations, and the Civil Registration System, to which reporting is mandatory of all changes of addresses in Greenland. Thus, information on vaccination dates and time at risk in Sisimiut is believed to be unbiased and of high quality. Furthermore, all information on risk factors was collected prospectively, minimizing the risk of recall bias and differential misclassification. In contrast, prior vaccination studies have largely relied on parental recall of vaccinations, either using postal surveys, telephone or personal parental interviews or reviews of school health records [6–11], with recall bias and incomplete registrations as possible consequences.

In Sisimiut we generally found high coverage rates for vaccinations scheduled before the age of 2 years, while those administered later (oral polio I–III) were somewhat lower. Compared with other countries, the coverage rates for vaccines given before the age of 2 (pertussis 1–3, DT-IPV 1–3, and MMR 1) are high. In Denmark, where all vaccinations are administered free of charge by general practitioners, the figures for pertussis 1–3 and DT-IPV 1–3 are of the same magnitude as in Sisimiut, but slightly lower for MMR 1 (between 81 and 88%) [3,12]. In the USA, where vaccines are only administered free of charge to children living below the poverty line, vaccine coverage rates for a total series of four DTP, three OPV and one MCV ('Measles containing vaccine') vaccines given before age 2 years were between 76 and 81% [13], while for a total series of three pertussis, three DT-IPV, and one MMR administered in Sisimiut, the corresponding figure was 88%, or almost 10% better than in the USA. In India, where the childhood vaccine programme is quite similar to the US programme, coverage rates in urban areas are between 73 and 92% for DTP 1–3 and OPV 1–3, for MCV 43%, and for a full series of three DTP, three OPV, one MCV and one BCG, 34.5% [14]. These figures are much lower than the corresponding figures in Sisimiut. Rates for specific vaccinations administered in rural areas in India are in general 20% lower than those in urban areas [14], and thus much lower than in Sisimiut.

Children from the settlements received their vaccinations delayed compared with children from Sisimiut town. This is not surprising, as the health visitors only have opportunities to vaccinate the children 3–6 times a year, unlike the children in Sisimiut town. It was surprising, however, that total vaccine coverage rates were equal in Sisimiut town and the settlements despite the health visitors' few and irregular visits. In contrast, studies from developing countries show that children from rural areas have lower vaccine coverage rates than urban children [14–16]. A likely explanation for the high coverage rates both in Sisimiut town and the settlements may be that health visitors handled vaccinations as a specific task. Thus, they called in all relevant children for vaccination on a specific weekday and kept record not only of planned and administered vaccinations, but also of children who had not shown up on the scheduled day, in which cases reminders were sent out. In most other places where doctors perform the vaccinations, parents have to keep record of the scheduled vaccination times and make arrangements themselves.

The proportion of children who receive their vaccinations within one month after the scheduled time compared with later decreased with age. For pertussis in particular this is disadvantageous, as the purpose of the vaccination in Greenland/Denmark is not to eliminate pertussis like in other countries, but to delay the time of infection [2,17]. At a later age the natural course of the infection is much less severe than in infancy, when it may be lethal. Thus, it is unfortunate that the pertussis 3 vaccine is administered with delay to more than 30% of children.

Children moving into Sisimiut had a significantly lower vaccine coverage rate (53.2%) for all vaccines at 2 years of age compared with children who had lived in Sisimiut since birth (92.6%). This is in line with findings from the USA, where newcomers had lower vaccine coverage rates than residents [18]. By further analysis we found that of the immigrants in Sisimiut approximately half had not at all been registered in the vaccination files, indicating that no contact had taken place between these children and the vaccination system. The most likely explanation for this is that parents of immigrants in Sisimiut have to contact the health visitors themselves to inform the vaccination system that they have moved into Sisimiut. This suggests that the low coverage rate among immigrants may be improved by changing this pattern towards active contact to immigrants. Immigrants, however, might still have been vaccinated elsewhere in earlier periods of their lives, but as the purpose of the present study was to evaluate whether the planned vaccines were given in Sisimiut according to schedule, this is irrelevant to the present study.

Children of Danish or mixed origin had significantly higher vaccine coverage at 2 years of age than children of pure Greenlandic origin, corresponding to studies from studies from other parts of the world, which have found ethnicity to be associated with coverage [19–22]. The fact that children from households with smokers had lower coverage

rates could reflect ethnicity, as Greenlanders smoke much more than Danes in Greenland. A further explanation for the latter could be, however, that non-smoking parents are more concerned with disease prevention than smoking parents. Similarly, parents to children with many respiratory tract infections might be more motivated to have their children vaccinated.

In conclusion, the vaccine coverage in Sisimiut municipality is on the same level as in Western countries, even though access to general practitioners in Greenland in comparison is less easy. The vaccination model in Greenland, where vaccinations are administered free of charge by health visitors, seems to be effective, in particular as regards vaccination of children living in settlements. Thus, the model may therefore be used with advantage in other countries with limited access to doctors but with contact to health visitors or similar medical persons. Greenlandic ethnicity, exposure to passive smoking, immigration to the area after birth, and having fewer episodes of respiratory tract infections than on average were associated with low vaccine coverage rates. While some of these factors probably reflect parental attention to vaccination, others may reflect realistic targets for improvement. Thus, even as the vaccination system seems efficient, higher vaccine coverage rates in Greenland might be achieved through changes in routines. Paying more attention to immigrants and to children with low morbidity might have this effect.

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