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Socioeconomic inequalities and infant mortality of 46 470 preterm infants born in Sweden between 1992 and 2006

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Summary

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Studies on possible sociodemographic inequities in the survival of preterm infants are scarce. Individual and neighbourhood sociodemographic factors are related to preterm birth and to infant mortality in full-term infants. The aim here was to examine whether infant mortality in Swedish preterm infants is related to individual and neighbourhood sociodemographic factors, and to study whether the hypothesised association between neighbourhood deprivation and infant mortality persists after accounting for individual sociodemographic factors.

The study included 46 470 infants with a gestational length of <37 weeks, born in Sweden between 1992 and 2006. Neighbourhood deprivation was assessed by an index (education, income, unemployment, welfare assistance) in small geographical units, and categorised into low, moderate and high deprivation. Adjusted odds ratios for infant mortality were examined in relation to individual and neighbourhood sociodemographic factors.

After adjusting for maternal age, infant mortality was associated with the following sociodemographic variables: maternal non-married/non-cohabiting status, low family income, low maternal education and rural status. After full adjustment, the odds ratio [95% confidence interval] was 2.98 [2.42, 3.67] for low family income compared with high family income. An increase in infant mortality was also associated with high neighbourhood deprivation; however, this increased risk no longer remained statistically significant after adjusting for individual sociodemographic factors. In conclusion, this study showed an increased infant mortality in preterm infants born to women with a less favourable sociodemographic profile.

Keywords: *deprivation*, *mortality*, *neighbourhood*, *preterm birth*, *socioeconomic status*.

Introduction

The purpose of the present study was to examine infant mortality in preterm infants in relation to a comprehensive set of individual and neighbourhood demographic and socioeconomic factors.

Preterm birth (PTB), defined as a gestational age <37 weeks, is a leading cause of infant morbidity and mortality in industrialised countries.[1–3] Prematurely born infants have a higher risk of several complications such as respiratory distress syndrome, severe infections and serious neurological conditions,[4–7] all of which can lead to substantial emotional costs for the affected families as well as high economic costs for the health care system.

Previous research has found associations between PTB and individual sociodemographic factors such as ethnicity[2] and socioeconomic status.[3,8] Moreover, neighbourhood-level factors are also associated with PTB.[9,10] For example, the overall risk of PTB is increased among women living in socioeconomically deprived neighbourhoods,[11,12] neighbourhoods with high crime rates[13] and neighbourhoods with poor social support.[14] As the sociodemographic circumstances often persist after the child has been born, it is

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of interest to determine whether these circumstances continue to influence the health of the preterm child.

Furthermore, there are well-known associations between sociodemographic factors and infant morbidity and mortality in full-term infants.[15–17] Data from the Office for National Statistics in the UK have indicated that infant mortality is related to such parental sociodemographic factors as ethnicity, marital status and occupation[18] and to area-level deprivation.[19]

Although previous studies have shown: (i) associations between sociodemographic factors and PTB, and (ii) associations between sociodemographic factors and infant mortality in full-term infants, whether the mortality in preterm infants varies with individual and neighbourhood demographic and socioeconomic factors has not been fully investigated.[20] The key strengths of the present study are as follows: (a) a large cohort of 46 470 preterm infants born between 1992 and 2006; (b) the use of a comprehensive set of individual sociodemographic factors as well as neighbourhood deprivation data, and (c) a more accurate determination of gestational length than in many previous studies because of the frequent use of ultrasound examinations.

The first aim of the study was to examine whether infant mortality in Swedish PTB infants is related to individual and neighbourhood sociodemographic factors. The second aim was to examine whether the hypothesised association between neighbourhood deprivation and infant mortality in PTB infants persists after accounting for individual sociodemographic factors.

Methods

Study population and data sources

The study population consisted of an open cohort of preterm infants born between 1 January 1992 and 31 December 2006 to all first-time mothers aged between 20 and 44 in Sweden. Only singleton preterm livebirths were included in the study. Data were retrieved from a national research database, WomMed II, located at the Center for Primary Health Care Research at Lund University. This database contains information on maternal and infant factors at both the individual and neighbourhood level. The information in WomMed II was collected from a number of Swedish national registries, such as the Swedish Medical Birth Register, the National Patient Register (sometimes called the Swedish Hospital Discharge Register) and the Swedish Cause of Death Register. Information on individual and neighbourhood level sociodemographic factors was retrieved from the Swedish Total Population Register that was delivered to us from the Swedish government-owned statistics bureau.

Definition of PTB and outcome

All pregnant women in Sweden are offered free antenatal care. At the first antenatal visit, usually during gestational weeks 10–12, information on the date of the last menstrual period is obtained. In addition, between gestational weeks 16–18, nearly all women (95% or more)[21] have an ultrasound examination to date their pregnancy and calculate the expected date of delivery. At the time of birth, the gestational age is estimated based on the ultrasound examination. In the few cases for which ultrasound is missing, the last menstrual period is used. PTB was defined as birth <37 weeks of gestation and very preterm as <33 weeks of gestation. A combination of gestational age, birthweight and infant sex was used to determine small for gestational age (SGA) at birth. Babies that were more than two standard deviations (SDs) below the mean for gestational age were defined as SGA[22]. The outcome variable was defined as the mortality of preterm infants who were born alive.

Individual sociodemographic variables

All individual variables were defined for each woman for the year that her child was born or at the birth of the child.

Maternal age was divided into 5-year age groups: 20–24, 25–29, 30–34, 35–39 and 40–44 years.

Marital status was categorised as: (1) married or cohabitating, and (2) never married, widowed, divorced or non-cohabiting. It should be noted that child-bearing in cohabitating couples is common and socially accepted in Sweden.

Family income was calculated from the annual family income divided by the number of family members (i.e. individual family income per capita). This variable was provided by the Swedish government-owned statistics bureau. The income calculation was weighted and took into account the ages of the people in the family. For example, children were given lower consumption weights than adults. The calculation was performed as follows: the sum of all family members' incomes was

multiplied by the individual's consumption weight divided by the family members' total consumption weight. The final variable was calculated as empirical quartiles from the distribution.

Educational attainment was divided into: (1) completion of compulsory school or less (≤9 years); (2) practical secondary school, or some theoretical secondary school (10–11 years), or (3) completion of theoretical secondary school and/or college/university (≥12 years).

Immigrant status: Information was available on which country the women were born in. These countries were categorised as 'Western' (Western Europe, US, Canada, Oceania) and 'Others' (rest of the world).

Mobility was classified as 'not moved' or 'moved' to another neighbourhood during the 2 years prior to childbirth. Mobility was included in the model to minimise misclassification of the neighbourhood exposure.[23]

Urban/rural status was classified as living in a (1) large city, (2) middle-sized town, or (3) small town or rural area. This variable was included because urban/rural status has been associated with infant mortality and may be associated with access to high-quality neonatal care.[8]

Neighbourhood deprivation

The home addresses of all Swedish women have been geocoded into small geographic units having boundaries defined by homogeneous types of buildings. These units, called small area market statistics (SAMS), have an average of 1000 to 2000 people each, and were used as proxies for neighbourhoods, corresponding to previous research.[24–26] The total number of SAMS included in the present study was 8409.

Neighbourhood of residence is determined annually using the National Land Survey of Sweden register. In the analyses, neighbourhood of residence was defined for the 2 consecutive years prior to childbirth in order to ensure that the correct neighbourhood of exposure was assessed for all women. A summary measure was used to characterise neighbourhood-level deprivation. We identified deprivation indicators used by past studies to characterise neighbourhood environments and then used a principal components analysis to select deprivation indicators in the national database. The following four variables were selected for those aged 25–64: low educational status (<10 years of formal education), low income (income from all sources, including that from interest and dividends, defined as <50% of individual median income), unemployment (not employed, excluding full-time students, those completing compulsory military service and early retirees) and social welfare recipient. Each of the four variables loaded on the first principal component with similar loadings (+0.47 to +0.53) and explained 52% of the variation between these variables. A z score was calculated for each SAMS neighbourhood. The z scores, weighted by the coefficients for the eigenvectors, were then summed to create the index. The index was categorised into three groups: below one SD from the mean (low deprivation), above one SD from the mean (high deprivation) and within one SD of the mean (moderate deprivation). Higher scores reflect more deprived neighbourhoods.[24–26]

Statistical analysis

Mortality rates in the PTB infants were calculated separately for each category of the individual variables and across the three categories of neighbourhood deprivation.

Logistic regression models were used to estimate adjusted odds ratios (ORs) with 95% confidence intervals (CIs) for infant mortality in relation to the individual and neighbourhood variables. Adjustments were made in two steps. Firstly, separate analyses were conducted for each variable, adjusted for maternal age. Secondly, the same analyses were made with full adjustments for all covariates, that is, infant sex, gestational age, SGA, maternal age, maternal marital status, maternal education, family income, immigrant status, urban/rural status, mobility and neighbourhood deprivation. All variables were entered as categorical variables. Interaction tests between the individual variables and the neighbourhood variable were performed. The SAS Statistical Package (version 9.2) was used for all statistical analyses.

Ethical considerations

This study was approved by the Ethics Committee of Lund University.

Results

There were 836 037 infants born among the study population of women who had their first singleton birth between 1 January 1992 and 31 December 2006.

Out of this number, 46 470 (5.6%) infants were classified as PTB. Baseline characteristics of all PTB infants are presented in Table 1.

Mortality

Among the preterm infants, 1335 (2.9%) died during their first year (Table 2). The PTB mortality rates were higher in boys, in infants born very preterm (<33 weeks of gestation) and in infants born SGA. Furthermore, the mortality rates were higher in infants with older mothers (>age 30), non-married/non-cohabiting mothers, mothers with low-level education and in infants born in rural areas or in families with low income. The PTB mortality rates increased with higher neighbourhood deprivation for each individual variable, the only exception being low family income. Interaction tests showed statistically significant and clinically meaningful interactions between family income and deprivation. PTB children in families with low income had a lower infant mortality in more deprived neighbourhoods (OR 2.74 [95% CI 1.86, 4.06]). Tests for statistical significance and interactions are not, however, presented in Table 2.

Table 1. Baseline characteristics of the preterm infants (n = 46 470). Sweden, 1992–2006

	n	%
Infant sex		
Male	24 978	53.8
Female	21 492	46.2
Gestational age at birth		
≥33 weeks	37 852	81.5
<33 weeks	8 618	18.5
Small for gestational age at birth		
No	41 437	89.2
Yes	5 033	10.8
Maternal age (years)		
20–24	8 420	18.1
25–29	16 120	34.7
30–34	13 683	29.4
35–39	6 524	14.0
40–44	1 723	3.7
Maternal marital status		
Married/cohabiting	41 205	88.7
Non-married/non-cohabiting	5 265	11.3
Family income (quartiles)		
High income	7 575	16.3
Middle-high income	18 320	39.4
Middle-low income	14 316	30.8
Low income	6 259	13.5
Maternal educational attainment (years)		
≥12	25 995	55.9
10–11	13 814	29.7
≤9	6 661	14.3
Maternal immigrant status		
Sweden	39 496	85.0
Western countries	2 389	5.1
Others	4 585	9.9
Urban/rural status		
Large cities	13 807	29.7
Middle-sized towns	16 053	34.5
Small towns/rural areas	16 610	35.7
Mobility		
Not moved	36 779	79.1
Moved	9 691	20.9
Neighbourhood deprivation		
Low	8 756	18.8
Moderate	27 895	60.0
High	9 819	21.1

Table 3 shows the ORs for PTB mortality in relation to individual and neighbourhood sociodemographic factors, as estimated by logistic regression. Separate analyses were conducted for each variable, adjusted for age. There was a significantly increased mortality in boys, in infants with low gestational age and in SGA infants. There was also an increased infant mortality associated with the following individual-level sociodemographic categories: non-married/non-cohabiting mothers, low family income, low maternal education and rural status, after adjusting for maternal age. After full adjustment, there was a clear dose–response relationship for family income and maternal age. The adjusted OR [95% CI] for low family income was 2.98 [2.42, 3.67], using high family income as reference in the full model.

The age-adjusted OR [95% CI] for mortality in preterm infants born in high-deprivation neighbourhoods was 1.33 [1.12, 1.58], compared with preterm infants born in low-deprivation neighbourhoods. After adjusting for the individual covariates, the increased risk did not remain statistically significant.

Discussion

This study of 46 470 Swedish preterm infants showed that certain individual sociodemographic factors were associated with increased infant mortality. These individual factors were advanced maternal age, low family income, low maternal education, living in a small town/rural area and having a mother who is not married or cohabiting. In addition, there was an increased infant mortality rate related to high neighbourhood deprivation, but this increased risk no

Table 2. Numbers and proportions of infant mortality in 46 470 preterm infants in relation to individual sociodemographic variables and neighbourhood deprivation

			Neighbourhood deprivation					
	All		Low		Moderate		High	
	n	%	*n*	%	*n*	%	*n*	%
All	1335	2.9	234	2.7	767	2.7	334	3.4
Infant sex								
Male	774	3.1	142	3.1	437	2.9	195	3.7
Female	561	2.6	92	2.2	330	2.6	139	3.1
Gestational age (weeks)								
≥33	440	1.2	71	1.0	262	1.2	107	1.3
<33	895	10.4	163	10.6	505	9.7	227	12.0
Small for gestational age								
No	961	2.3	167	2.1	567	2.3	227	2.6
Yes	374	7.4	67	7.6	200	6.7	107	9.3
Maternal age (years)								
20–24	244	2.9	23	2.6	126	2.5	95	3.7
25–29	411	2.5	66	2.4	251	2.5	94	2.8
30–34	394	2.9	87	2.8	234	2.9	73	3.1
35–39	221	3.4	46	2.9	118	3.2	57	4.7
40–44	65	3.8	12	2.8	38	4.1	15	4.2
Maternal marital status								
Married/cohabiting	1128	2.7	208	2.6	647	2.6	273	3.3
Non-married/non-cohabiting	207	3.9	26	3.1	120	4.0	61	4.3
Family income (quartiles)								
High income	170	2.2	74	2.6	74	1.8	22	3.5
Middle-high income	343	1.9	60	1.8	217	1.8	66	2.2
Middle-low income	421	2.9	50	2.8	245	2.9	126	3.1
Low income	401	6.4	50	6.7	231	6.8	120	5.6
Maternal educational attainment (years)								
≥12	676	2.6	158	2.6	382	2.5	136	3.1
10–11	439	3.2	57	2.7	277	3.2	105	3.5
≤9	220	3.3	19	2.8	108	3.0	93	3.9
Maternal immigrant status								
Sweden	1120	2.8	214	2.7	679	2.7	227	3.4
Western countries (Western Europe, US, Canada, Oceania)	78	3.3	7	1.9	38	3.3	33	3.8
Others	137	3.0	13	2.7	50	2.8	74	3.2
Urban/rural status								
Large cities	371	2.7	105	2.6	181	2.5	85	3.2
Middle-sized towns	464	2.9	81	2.7	280	2.8	103	3.4
Small towns/rural areas	500	3.0	48	2.7	306	2.9	146	3.5
Mobility								
Not moved	1045	2.8	172	2.7	625	2.7	248	3.5
Moved	290	3.0	62	2.7	142	3.1	86	3.1

longer remained statistically significant after adjusting for the individual sociodemographic factors.

Although it is known that infant mortality is associated with sociodemographic factors in full-term infants,[15,16,18,19] corresponding studies on preterm infants are scarce. A recent study examined infant mortality in very preterm infants before discharge from hospital in relation to deprivation in geographic units with about 1500 residents.[20] That study found no increased mortality risk in highly deprived areas but it had no access to individual-level measures of deprivation. A possible explanation behind these negative findings is that they were based on hospital data before discharge and that the potential effects of

Table 3. Odds ratios (ORs) and 95% confidence intervals (CIs) for infant mortality in the preterm infants

	Maternal age-adjusted model		Full model		
	OR	95% CI	OR	95% CI	P^b for whole variable
Infant sex					0.001
Male	1.00	Reference	1.00	Reference	
Female	0.84	[0.75, 0.94]	0.82	[0.73, 0.92]	
Gestational age (weeks)					<0.001
≥33	1.00	Reference	1.00	Reference	
<33	9.83	[8.75, 11.05]	8.52	[7.55, 9.61]	
Small for gestational age					<0.001
No	1.00	Reference	1.00	Reference	
Yes	3.35	[2.96, 3.80]	1.77	[1.55, 2.02]	
Maternal age (years)[a]					<0.001
20–24	1.00	Reference	1.00	Reference	
25–29	0.88[a]	[0.75, 1.03]	1.08	[0.91, 1.28]	
30–34	0.99[a]	[0.85, 1.17]	1.24	[1.04, 1.479	
35–39	1.18[a]	[0.98, 1.41]	1.29	[1.05, 1.57]	
40–44	1.32[a]	[1.00, 1.74]	1.42	[1.06, 1.91]	
Maternal marital status					0.775
Married/cohabiting	1.00	Reference	1.00	Reference	
Non-married/non-cohabiting	1.46	[1.26, 1.70]	0.91	[0.77, 1.07]	
Family income (quartiles)					<0.001
High income	1.00	Reference	1.00	Reference	
Middle-high income	0.90	[0.75, 1.09]	0.85	[0.70, 1.03]	
Middle-low income	1.50	[1.24, 1.80]	1.36	[1.11, 1.65]	
Low income	3.42	[2.84, 4.13]	2.98	[2.42, 3.67]	
Maternal educational attainment					0.431
Theoretical secondary school and/or college (≥12 years)	1.00	Reference	1.00	Reference	
Practical secondary school or some theoretical secondary school (10–11 years)	1.24	[1.09, 1.40]	1.14	[1.00, 1.29]	
Compulsory school or less (≤9 years)	1.31	[1.12, 1.52]	1.04	[0.88, 1.22]	
Immigrant status					0.023
Sweden	1.00	Reference	1.00	Reference	
Western countries (Western Europe, US, Canada, Oceania)	1.13	[0.89, 1.42]	0.97	[0.76, 1.25]	
Others	1.04	[0.87, 1.25]	0.77	[0.63, 0.94]	
Urban/rural status					0.354
Large cities	1.00	Reference	1.00	Reference	
Middle-sized towns	1.10	[0.96, 1.26]	1.13	[0.98, 1.31]	
Small towns/rural areas	1.15	[1.00, 1.32]	1.15	[0.99, 1.33]	
Mobility					0.212
Not moved	1.00	Reference	1.00	Reference	
Moved	1.07	[0.94, 1.22]	1.07	[0.93, 1.23]	
Neighbourhood deprivation					0.685
Low	1.00	Reference	1.00	Reference	
Moderate	1.05	[0.91, 1.22]	0.91	[0.77, 1.06]	
High	1.33	[1.12, 1.58]	0.99	[0.82, 1.20]	

The age-adjusted model shows separate age-adjusted analyses for each variable (i.e. row). The full model represents a single analysis where adjustments are made for all the included variables simultaneously.

[a]ORs (not adjusted for age).

[b]Full model.

area deprivation do not appear until after hospital discharge.

A recent study from Sweden showed that the overall mortality of preterm infants during their first year was lower than in many other countries.[27] It was suggested that the favourable results could at least partly be explained by the high quality of neonatal care in Sweden and a proactive approach to perinatal and neonatal care with high intervention rates. Infant mortality and relative differences between social groups declined dramatically in Sweden during the 20th century, as a result of improved health conditions in general and effective preventive child health care.[28,29] Today, medical coverage and free antenatal care are provided to all permanent residents, and health care clinics are equally distributed in all types of neighbourhoods.[26]

Despite the Swedish welfare system and the free access to prenatal health care and health care for children up to 18 years, the social gradient in adverse birth outcomes and infant mortality is similar to other industrialised countries.[8,16,20,29,30] In addition, there is a continuous socioeconomic gradient for other health-related outcomes in infants and children in Sweden, such as cerebral palsy,[31] medication for attention-deficit/hyperactivity disorder[32] and psychiatric disorders.[33]

It is likely that major mechanisms behind sociodemographic inequalities in infant mortality in Sweden are broadly similar compared with other industrialised countries. For example, the tendency to seek medical care and the adherence to preventive measures might vary with sociodemographic factors and cultural beliefs.[26,34] The present study showed that living in a small town or rural area was associated with increased mortality in PTB infants, suggesting that living in a more rural area may be associated with limited access to high-quality neonatal care, which is supported by earlier studies.[8] High-level maternal education has earlier been associated with reduced infant mortality and may, for example, be associated with a better knowledge of infant care.[8,29] Furthermore, significant and clinically meaningful interactions were found between family income and deprivation. PTB children in families with low income had a lower infant mortality in more deprived neighbourhoods. These results may reflect the possibility that many socioeconomically disadvantaged families have their social networks in deprived neighbourhoods rather than in affluent neighbourhoods.

Socioeconomic factors such as poverty, unemployment and exposure to crime and violence have been shown to be associated with increased psychological stress.[35] Furthermore, it has been reported that maternal stress is related to smoking and other maladaptive health behaviours.[36] It is well known that stress is associated with dysregulation of the hypothalamic pituitary adrenal axis and increased morbidity.[37] Mothers exposed to high levels of psychological or social stress, or exposed to objectively stressful conditions, such as housing instability and severe material hardship, have increased risks of giving birth prematurely.[36,38] The hypothalamic pituitary adrenal axis is highly susceptible to programming during fetal and neonatal development.[37] According to the 'Barker hypothesis', early environmental stress can increase the vulnerability to disease later in life.[39] It has been reported that cortisol levels differ in preterm infants compared with term infants, indicating a dysregulation of the axis among these infants.[40] Although data on stress hormones were not available to us, the results of the present study may suggest that both maternal and infant stress can be part of the pathway between low socioeconomic status and increased infant mortality in PTB infants.

Methodological strengths and limitations

This study has several methodological strengths, some of which have been mentioned earlier. Firstly, we had access to a large number of preterm infants during a period of 15 years. The data were drawn from the entire population of Swedish women aged 20–44, which allowed generalisability and validity of the results. Secondly, the cohort includes a comprehensive set of individual sociodemographic factors as well as neighbourhood deprivation data, with a high degree of completeness of data. The data from the Swedish Population Register and the geocoded addresses were particularly complete: 98% or more of the individual sociodemographic data and 97% of the geocoded addresses were complete. The SAMS units, used to define neighbourhoods, are relatively small and homogeneous geographical units. Such small neighbourhoods have been shown in qualitative studies to be consistent with how residents themselves define their neighbourhoods.[41] Thirdly, gestational length was determined with a high level of validity because of the frequent use of ultrasound examinations in Swedish maternity clinics.

There are also limitations. We had no access to data on health behaviours such as smoking, which is related to PTB and infant mortality.[3,19] It is well known that smoking is strongly related to low socioeconomic status, and could therefore be regarded as one of the mechanisms behind the relationship between socioeconomic status and infant mortality in PTB infants.[26,42] Residual confounding is also possible, because socioeconomic status cannot be measured entirely by the socioeconomic indicators in population registers. However, it is also important to consider the possibility of 'over-controlling' for factors in the pathway between neighbourhood deprivation and infant mortality, because it is plausible that neighbourhood deprivation partially determines the socioeconomic attainment of the residents. Thus, control for individual-level covariates in our full model may have over-adjusted for the 'true' effects of the neighbourhood context.

The use of multilevel modelling techniques is common in many neighbourhood studies.[43] However, appropriate use of multilevel modelling to estimate random effects requires an adequate number of cases in each neighbourhood. As infant mortality is a relatively rare outcome in Western countries, we had too few cases in each neighbourhood. The use of multilevel models in this study would violate one of the assumptions when using a multilevel model, namely that the residuals are normally distributed. Therefore, multilevel modelling was not appropriate in our study. Instead, ordinary logistic regression models were used. Previous studies have used a similar analytical approach.[24] In addition, because of the large sample size, low outcome incidence rate and short follow-up, logistic regression was appropriate instead of Cox proportional hazards model, as has been suggested.[44]

Conclusion

This study demonstrated increased infant mortality in preterm infants born to women with a less favourable sociodemographic profile. Although improvements in perinatal and neonatal care have led to increased survival of infants born prematurely, socioeconomic inequities in the survival of prematurely born infants still do exist even in such an egalitarian society as in Sweden. Further research is needed to investigate possible mechanisms behind these findings.

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