Three Decades of Inequality in Neonatal and Early Childhood Mortality in Singleton Births in Scotland

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Abstract

Background:

Socioeconomic inequality in child mortality highlights opportunities for policies to reduce child deaths.

Methods:

We used singleton birth, death and maternity records from Scotland, 1981-2011, to examine mortality rate differences by age across deprivation quintiles over time. We measured the difference between the most and least deprived quintiles (Q5-Q1) and the slope index of inequality (SII) across all quintiles – measures of the absolute deprivation gap , providing an indication of the public health impact.

Results:

Q5-Q1 remained relatively constant from the 1990s onwards for early neonates; widened in the mid-2000s for late neonates; increased in the 1990s then decreased in the 2000s in the post neonates and declined over time in early childhood. The trend over time in SII showed no significant change for early neonates (p=0.440), significant decrease for post neonates (p=0.010) and early childhood (p=0.043), and significant increase for late neonates (p=0.011).

Conclusions:

Over three decades, the absolute deprivation gap in mortality widened in late neonates, but stabilised or declined at other ages. This may reflect improved survival beyond the early neonatal period of babies with conditions related to socioeconomic inequality such as prematurity. Monitoring birth cohort data could enhance understanding of this vulnerable group.

BACKGROUND

Impressive reductions in infant mortality have been achieved over recent decades, but inequality between socioeconomic groups has persisted.[1 2 3]

One in four children are reported to be living in relative poverty in the UK.[4] These children may be more at risk from factors such as unsuitability of the built environment for safe activities.[5] Differential changes in such factors could effect the extent of the mortality gap between deprivation groups over time. Additionally at a wider contextual level, it is considered that institutional policies and programs, both in and outside of the health sector,[6 7] can influence health inequalities.

In this paper, we use birth registration data for Scotland from 1981 to 2011 to compare inequalities in mortality rates between socioeconomic groups, using the Carstairs score, a postcode sector based measure of deprivation.[8] These 30 years spanned interventions associated with reductions in infant deaths, including the introduction of surfactant treatment for neonates with respiratory distress in the 1990s,[9] the promotion of placing babies to sleep on their back in the early 1990s, and the 2006 ban on smoking in public places.[10] This same time period also spanned economic changes including a large increase in income inequality in the UK between the late 1970s and early 1990s,[11] as well as changes in the demography of parenting with an increase in the age at first birth[12] where the older mother tends to be of higher socioeconomic status but also more prone to pregnancy complications.[13]

Monitoring of changes in inequalities in child mortality, and the age at which inequalities are largest, can inform preventive strategies. Neonatal mortality (0-27 days) is strongly linked to early gestational age.[14 15] Thus inequalities in neonatal mortality might be reduced by strategies to reduce preterm birth[16] such as smoking bans[17] or strategies to improve neonatal care.[18] In contrast, inequalities in post-neonatal mortality may be reduced by strategies to improve support for parents caring for babies at home, by reducing parental use of drugs or alcohol, placing babies to sleep on their back and avoiding co-sleeping, all of which are risk factors for sudden unexpected infant death.[19] Moreover within the neonatal group there are differences between early (0-6 days) and late (7-27 days) neonatal mortality; preterm and intrapartum complications account for a higher proportion of early neonatal deaths, while infections account for a higher proportion of late neonatal deaths.[20]

The deprivation gap can be measured in relative terms as a ratio (mortality rate in most deprived divided by the mortality rate in least deprived quintile) or by the relative index of inequality (RII) taking into account all Carstairs quintile groups. Alternatively the deprivation gap can be measured in absolute terms as a difference (mortality rate in most deprived minus mortality rate in least deprived quintile) or by the slope index of inequality (SII) taking into account all Carstairs quintile groups. The absolute difference between socioeconomic strata in the rates of child deaths at different ages measures the impact of socioeconomic inequalities on the population. However, previous studies have mainly focussed on the relative deprivation gap,[3 21] which has an advantage in epidemiological risk studies of being independent of the underlying prevalence, and is more comparable between populations.[22 23] The absolute difference in rates or absolute deprivation gap is not independent of underlying prevalence but gives a better indication of the impact of deprivation on childhood death, by providing a measure of the magnitude of the effect on the population. We focussed on the absolute rather than relative deprivation gap since it provides an indication of the size of the public health impact.[24] We investigated trends over time in the absolute deprivation gap in early and late neonatal, postneonatal and early childhood mortality by examination of successive birth cohorts.

METHODS

Data sources (Figure 1).

We used the Scottish birth registration file to provide a record of all singleton live births in Scotland 1981- 2011. We linked birth registration records to maternity and death registration files using a patient identification number. We excluded 11,083 birth records that could not be linked to the other files because personal identifiers were insufficient for linkage to other files. We excluded any multiple birth records (since mortality rates are higher in multiple births compared to singletons and there were changes in rates of assisted reproduction over time) using multiple birth variables recorded in either the birth registration or the maternity files, leaving a population of 1,817,525 births (Figure 1). We used the Scottish death registration file to provide death data, and cleaned the file removing records where the date of death was recorded as before the date of birth from the birth registration file or where the date of death was before January 1981.

Coding of variables.

Deprivation: We used an area-based measure of deprivation called Carstairs scores**,** constructed at postcode sector level. Carstairs scores were created in 1981 to provide a population measure of deprivation based on four census variables, car ownership, male unemployment, overcrowding and low social class.[8 25] Since then the scores have been updated decenially but variable definitions have been kept as similar as possible to those used in 1981. We used the Carstairs indicators nearest the year of birth to derive the deprivation status.[26] A Carstairs quintile variable, derived from population based Carstairs, was recorded for 99.67% of individuals in the birth registration file.

Age at death: We classed age at death as 0-27 days (neonatal), 0-6 days (early neonatal) and 7-27 days (late neonatal), 1 month-<1 year (post-neonatal) and early childhood (1-<5 years).

Gestation: Gestational age at birth was provided in the maternal datasets and used to examine the prevalence of preterm birth rate over the 30 year period (Appendix Table A1). Values less than 20 weeks were replaced as missing since this is below the limit of viability.[27] Due to a high proportion of missing gestational age values in children who died (27.8%), gestation-specific mortality rates were not analysed. Preterm birth rate was calculated as number of singleton preterm births (20-36 weeks gestation) divided by the number of all singleton births (Appendix Table A1). Additionally preterm birth rates were calculated with those missing gestation excluded .

Date of birth: We analysed period of birth yearly and in six-year group eras (1982-87, 1988-93; 1994-99; 2000-05 and 2006-11) to ensure adequate numbers of deaths in each age at death group for analyses.

Analysis

We derived the proportion of deaths in each year of birth for each Carstairs quintile in age-at-death groups, neonatal, early neonatal and late neonatal, post-neonatal and early childhood. For calculations of age-specific mortality rates, the numerator was the number of deaths in children born in each calendar year and the denominator was the total number of live births in each calendar year at birth (for simplicity deaths were not excluded from the denominator). Calculation of mortality rates was by birth year rather than calendar year at death. This ensured that discrete yearly cohorts were examined, where cases in the numerator of a rate are included in the denominator, avoiding problems with large changes in the total number of births. The years of birth used were 1981-2011 for neonatal and post-neonatal deaths, and 1981-2007 for early childhood deaths, where the final years were not used due to incomplete follow-up time.

We plotted graphs of the age-specific mortality rates in the least and most deprived quintiles by birth year to view the trend over time. We smoothed the yearly mortality rates by averaging the yearly value with the two closest yearly values (the first and last values were averaged with their single closest available yearly value). In a sensitivity analysis to examine the effect of exclusion of multiple births on the results the same graphs were plotted without excluding multiple births (Appendix Figure A1).

Additionally we analysed changes over time in mortality rates for each age at death group by era of birth rather than yearly. Absolute differences and their 95% confidence intervals (Table 1) were calculated between the most deprived and least deprived Carstairs quintiles at each era using the STATA cohort study (cs) package. The ratio of the most deprived to least deprived is also shown with their 95% confidence intervals (Table 1). Additionally we calculated the slope index of inequality (SII) and relative index of inequality (RII) as well as their trend over the eras.[28] These indices are regression based and take the whole socioeconomic distribution into account. We transformed the Carstairs level at each era into a summary measure scaled from zero to one. We assigned the population in each Carstairs category a modified riditscore based on the midpoint of the range in the cumulative distribution of the population of participants in the given category. We used generalised linear models (logbinomial regression), with a logarithmic link function for calculation of the relative index of inequality (RII) and with an identity link function for calculation of the slope index of inequality (SII) for each age-specific mortality outcome in each era. We assessed trends in RII and SII over time by the inclusion of the two-way interaction term riditscore by era for each age-specific mortality outcome.

Absolute differences in preterm birth rate and their 95% confidence intervals (Appendix Table A1) were calculated between the most deprived and least deprived Carstairs quintiles at each era both including and excluding those missing gestation. The group missing a gestation value were compared to those not missing a gestation value in terms of Carstairs quintile.

Analysis and graphing was performed using Stata 13 and Excel 2013. P values <0.05 were considered statistically significant.

RESULTS

The total number of births and deaths between 1981-2011 (after exclusions) was 1,817,525 and 19,620 repectively. The deaths included 1,707 and 1,022 neonatal deaths, 1,266 and 592 post-neonatal deaths and 569 and 258 early childhood deaths in the most deprived and the least deprived population quintiles respectively.

The absolute deprivation gap for early neonatal death declined between the early and late 1980s and remained relatively constant from the 1990s onwards (Figure 2a and Table 1). The trend in SII was non significant. (p=0.440) (Table 1).

For late neonatal death, the absolute deprivation gap widened in the mid-2000s and was higher in the 1990s onwards than in the 1980s (Figure 2b). The highest absolute deprivation gap of the five eras was 2000-05, followed by the most recent era 2006-11

(Table 1). The trend in SII showed a significant increase over the eras (p=0.011) (Table 1).

For post-neonatal deaths the absolute deprivation gap increased in the 1990s and decreased in the 2000s (Figure 2c). The trend in SII showed a significant decrease over the eras (p=0.010) (Table 1).

The absolute deprivation gap for early childhood death declined over time (Figure 2d and Table 1). The trend in SII showed a significant decrease over the eras (p=0.043) (Table 1).

In general the changes in the relative deprivation gap over the 6-yearly eras reflect those found in the absolute deprivation gap; for early neonatal deaths the highest measurement was 2000-05, for late neonatal death there was an increase over time, and for post-neonatal death, a peak in 1994-99. However for neonatal deaths trend over time, there was a significant increase in RII over the eras (p=0.001) with no significant change in SII (p=0.561) and for early childhood deaths trend over time, a significant decrease in SII (p=0.043) but no significant change in RII over the eras (p=0.849) (Table 1).

Of the 1,817,525 birth lines (singleton births 1981-2011) 92,514 (5.1%) were missing a gestation value; 4.9% in the least deprived quintile versus 5.3% in the most deprived quintile. In analysis of the rate of preterm birth (20-36 weeks gestation) over the eras (1982-87, 1988-93, 1994-99, 2000-05, 2006-11), preterm birth was higher in the most deprived quintile than the least deprived, and increased in both groups over time up to 2000-05. Whether or not those missing gestation were included in the denominator, there was an increase in the difference in preterm birth between the least and most deprived groups from the era 1988-93 to 2000-05, followed by a decrease in the era 2006-11, when the rate of preterm birth in the most deprived quintile decreased (Appendix Table A1).

A sensitivity analysis including multiple births, showed trends over time in the most deprived and least deprived quintiles similar to that of singleton births alone (as in the main analysis as above) (Appendix Figure A1).

DISCUSSION

Main finding of this study

We found a reduction over the 30 years 1981-2011 in the absolute deprivation gap for mortality in the older age groups (the post-neonatal and early childhood groups). In the neonatal period we found a stable gap in mortality rates in the early neonatal period and an increase in the deprivation gap both in absolute and relative terms in the late neonatal period. We also found an increase in preterm birth over time in both deprived and non-deprived groups (from 1982-87 through 2000-05), which might underlie the lack of reduction in the absolute deprivation gap at the neonatal age.

The increase in the deprivation gap in mortality in the late neonatal period over time may be due to improvements in care early in life resulting in a postponement of deaths to a later age. Further work on the gestation of these babies, whether the deaths were in hospital or at home and cause of death will help to further identify this vulnerable group and to prescribe the appropriate preventive strategy. Electronic birth cohorts with maternal socioeconomic class and other characteristics linked with risk factors for death need to be set up and followed from birth into childhood.

What is already known on this topic

A previous study of changes in the deprivation gap at the neonatal age based on English data 1997-2007[22] reported that preterm birth was the most common cause of death, with babies born at less than 24 weeks of gestation showing the highest ratio of mortality in the most deprived group compared to the least deprived. The absolute deprivation gap in all cause neonatal mortality was found to reduce over the period 1997-2007 with a greater absolute reduction in the most deprived group than the least deprived, but early neonatal death was not reported separately from late neonatal death. It was suggested that in the extremely preterm group the wide deprivation gap is unlikely to be reduced by further progress in neonatal care and there is a need for a greater understanding of the mechanistic link between deprivation and prematurity.

Our findings of the increase and subsequent decrease in absolute deprivation gap for post-neonatal death are consistent with previous studies of the sleep-on-the-back campaign. Using Scottish data, an increase in the relative deprivation gap[21] associated with post-neonatal death was found following the introduction of the campaign, followed by eventual return to lower levels, despite sharp falls in mortality risks across the whole population. This was accounted for by a slower decline in the risk of sudden-infant-deaths in the more deprived population. The same phenomenon has been shown in US data.[29]

What this study adds

This study systematically examines the absolute deprivation gap (mortality rate in most deprived minus mortality rate in least deprived quintile and the slope index of inequality across all quintiles) in early and late neonatal, post-neonatal and early childhood ages separately over time, to examine the changing impact of deprivation on the population. Most previous studies report relative deprivation rates and to our knowledge, in those studies that do report the absolute deprivation gap, the comparison between early and late neonatal, post-neonatal and early childhood ages has not been detailed. This study uses Scottish data and results are specific to Scotland but the technique can be repeated on data from other places.

Future research is needed including identification of how the gap in mortality rates between deprivation groups depends on gestational age, with electronic birth cohorts based on linked administrative health records for mothers and babies stratified for gestational age, measuring all pregnancy outcomes (still and live births), as well as analyses to determine whether changes in the gap in mortality rates between deprivation groups is explained by changes in preterm birth. Methods to complete the missing values for gestational age at birth may be required.

Limitations of this study

Limitations of this study include data quality, particularly missing gestational age at birth data for a significant proportion of deaths. A second limitation is that stillbirths were not available for analysis so the whole spectrum of pregnancy outcomes could not be examined. A future study would include stillbirths as well as live births to measure the absolute deprivation gap in stillbirths over time.

Another limitation relates to the validity of the deprivation measurement, which is an area-based measure susceptible to the limitations of ecological studies. Both area-based and individually based socioeconomic data used together could improve the validity of the deprivation exposure.[25 30] Also, the validity of the Carstairs measurement, based on measures captured in the census for overcrowding, unemployment of men, low social class, and not having a car, might vary geographically, and more recently the score may be less reflective of deprivation than when first developed.[8] Additionally comparison over time is complicated by small changes in the definition of the four variables at each census, although the essential nature of the measure has remained over the four censuses. Despite these small changes we considered it more appropriate to use the Carstairs nearest the birth year (four different Carstairs measures covering three decades), rather than use one single measure throughout.

Conclusions

Despite declines in mortality over the last three decades, the absolute deprivation gap in mortality rates has remained stable for babies who die in the first week of life and increased for babies who died between one and four weeks of age. As the main cause of death in the neonatal period is prematurity, public health interventions to reduce inequalities in child deaths should focus on identifying and reducing the risk factors for preterm births that are linked to deprivation.

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Figure Legends

Figure 1. Flowchart showing the process of variable preparation from data sources and their linkage (births (central), deaths (right) and gestation (left)) in preparation of analysis file (singleton babies born 1981-2011).

Figure 2. Trends over time for death at early neonatal (0-6 days, Figure 2a), late neonatal (7-27 days, Figure 2b), post neonatal (1 month-<1 year, Figure 2c) and early childhood (1-<5 years, Figure 2d) ages by most and least deprived Carstairs quintiles, Q5 (solid line) and Q1 (dashed line) respectively (3 yearly smoothed rates).

Appendix Figure A1. Trends over time for death at early neonatal (0-6 days, Figure 2a), late neonatal (7-27 days, Figure 2b), post neonatal (1 month-<1 year, Figure 2c) and early childhood (1-<5 years, Figure 2d) ages by most and least deprived Carstairs quintiles, Q5 (solid line) and Q1 (dashed line) respectively (3 yearly smoothed rates) for all births including multiple births.

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Figure 1. Flowchart showing the process of variable preparation from data sources and their linkage (births (central), deaths (right) and gestation (left)) in preparation of analysis file (singleton babies born 1981-2011).

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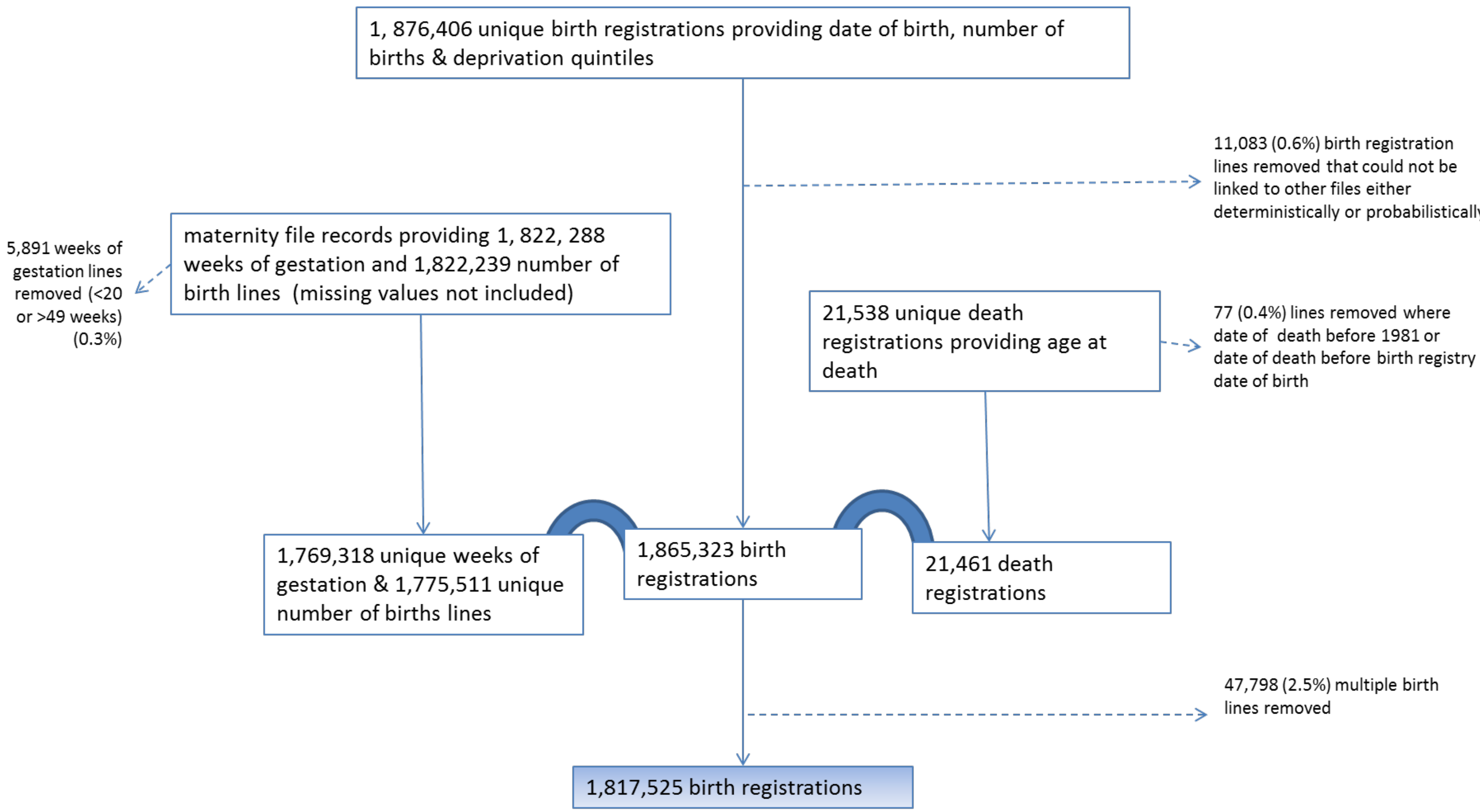
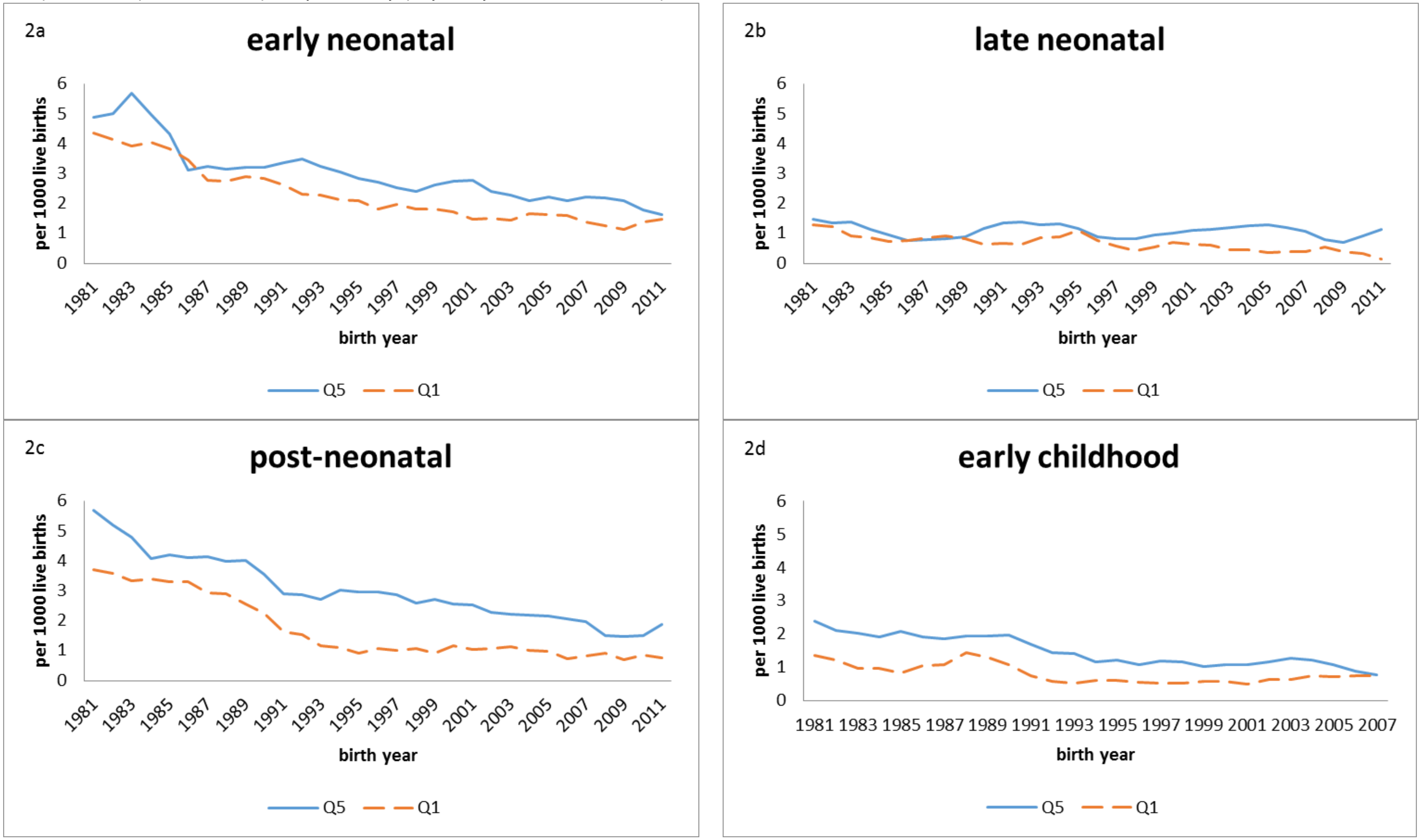


Table 1. Age-at-death specific mortality rates, absolute rate differences (per 1000 live births) and rate ratios between most and least deprived quintile (Carstairs quintile 5 (Q5) and 1 (Q1)) and slope and relative index across all quintiles by era.

		Q5		Q1		Q5-Q1		SII			Q5/Q1		RII		
		death rate	deaths total	death rate	deaths total	rate diff	95% CI	rate diff	95% CI	trend over time, p	rate ratio	95% CI	rate ratio	95% CI	trend over time, p
neonatal (0-27 days)	1982-87	5.44	464	4.53	321	0.91	0.21,1.61	1.18	0.38, 1.98		1.20	1.04,1.38	1.26	1.07,1.47	
	1988-93	4.49	392	3.33	228	1.15	0.53,1.77	1.33	0.64, 2.03		1.35	1.14,1.58	1.42	1.18, 1.70	
	1994-99	3.63	278	2.72	171	0.90	0.31,1.49	1.18	0.55, 1.82	0.561	1.33	1.10,1.61	1.50	1.21, 1.87	0.001*
	2000-05	3.63	250	2.11	122	1.52	0.93,2.10	1.77	1.11, 2.43		1.72	1.38,2.13	1.87	1.47, 2.36	
	2006-11	2.99	239	1.76	105	1.24	0.73,1.74	1.36	0.79, 1,94		1.70	1.36,2.14	1.79	1.40, 2.30	
early neonatal (0-6 days)	1982-87	4.36	372	3.70	262	0.66	0.03,1.29	0.99	0.27, 1.71		1.18	1.01,1.38	1.27	1.07, 1.51	
	1988-93	3.35	293	2.60	178	0.75	0.21,1.29	0.88	0.28, 1.49		1.29	1.07,1.55	1.36	1.10, 1.67	
	1994-99	2.62	201	1.96	123	0.66	0.16,1.17	0.90	0.35, 1.45	0.440	1.34	1.07,1.68	1.52	1.18, 1.96	0.131
	2000-05	2.44	168	1.58	91	0.86	0.37,1.35	1.00	0.43, 1.57		1.55	1.20,2.00	1.61	1.22, 2.12	
	2006-11	2.00	160	1.39	83	0.62	0.19,1.05	0.64	0.15, 1.13		1.44	1.11,1.88	1.46	1.09, 1.95	
late neonatal (7-27 days)	1982-87	1.08	92	0.83	59	0.25	-0.06,0.55	0.19	-0.16, 0.55		1.30	0.93,1.80	1.21	0.85, 1.74	
	1988-93	1.13	99	0.73	50	0.40	0.10,0.70	0.45	0.11, 0.79		1.55	1.10,2.18	1.64	1.13, 2.38	
	1994-99	1.00	77	0.76	48	0.24	-0.07,0.55	0.28	-0.04, 0.61	0.011*	1.31	0.92,1.88	1.45	0.96, 2.21	0.001*
	2000-05	1.19	82	0.54	31	0.65	0.33,0.97	0.74	0.41, 1.07		2.22	1.47,3.35	2.78	1.76, 4.39	
	2006-11	0.99	79	0.37	22	0.62	0.35,0.89	0.72	0.42, 1.01		2.69	1.68,4.31	3.11	1.92, 5.02	
post neonatal (1 mnth-<1 yr)	1982-87	4.43	378	3.32	235	1.11	0.50,1.73	1.31	0.65, 1.97		1.34	1.14,1.57	1.46	1.21, 1.76	
	1988-93	3.46	302	2.03	139	1.42	0.91,1.94	1.84	1.27, 2.41		1.70	1.39,2.08	2.01	1.62, 2.51	
	1994-99	2.78	213	0.99	62	1.79	1.35,2.24	2.07	1.58, 2.57	0.010**	2.81	2.12,3.73	3.13	2.35, 4.16	<0.0001*
	2000-05	2.35	162	1.02	59	1.33	0.88,1.78	1.58	1.12, 2.05		2.30	1.71,3.10	2.95	2.13, 4.08	
	2006-11	1.73	138	0.84	50	0.89	0.52,1.26	0.91	0.51, 1.31		2.07	1.50,2.86	2.25	1.59, 3.20	
early childhood (1-<5 yrs)	1982-87	1.97	168	1.00	71	0.97	0.59,1.34	1.11	0.67, 1.54		1.97	1.49,2.59	2.06	1.54, 2.76	
	1988-93	1.69	148	0.94	64	0.76	0.4,1.11	0.85	0.46, 1.23	0.043**	1.81	1.35,2.43	2.04	1.47, 2.81	0.849
	1994-99	1.19	91	0.57	36	0.61	0.31,0.92	0.64	0.28, 1.01		2.07	1.41,3.05	1.97	1.33, 2.93	
	2000-05	1.16	80	0.62	36	0.54	0.21,0.86	0.57	0.21, 0.93		1.86	1.26,2.76	1.97	1.28, 3.02	

*trend shows significant increase over time; ** trend shows significant decrease over time.

Figure 2. Trends over time for death at early neonatal (0-6 days, Figure 2a), late neonatal (7-27 days, Figure 2b), post neonatal (1 month-<1 year, Figure 2c) and early childhood (1-<5 years, Figure 2d) ages by most and least deprived Carstairs quintiles, Q5 (solid line) and Q1 (dashed line) respectively (3 yearly smoothed rates).



Appendix Table A1. Number of births by gestational age and percentage preterm by most (Q5) and least deprived (Q1) quintile, with difference between deprivation groups in percentage preterm, for singleton births in Scotland 1982-2011 (shown with missing gestation included in denominator and missing gestation excluded).

	N						Preterm %							
	Missing gestation		20-36 weeks		37+ weeks		Missing gestation included in denominator				Missing gestation excluded			
era	Q5	Q1	Q5	Q1	Q5	Q1	Q5	Q1	Q5-Q1	95% CI	Q5	Q1	Q5-Q1	95% CI
1982-87	5095	4487	4822	2776	75,431	63,624	5.6	3.9	1.7	1.5-1.9	6.0	4.2	1.8	1.6-2.1
1988-93	3010	2014	5241	3021	79,142	63,349	6.0	4.4	1.6	1.4-1.8	6.2	4.6	1.7	1.4-1.9
1994-99	3050	1606	4985	2800	68,597	58,380	6.5	4.5	2.0	1.8-2.3	6.8	4.6	2.2	2.0-2.4
2000-05	3383	2017	4749	2736	60,751	53,001	6.9	4.7	2.2	1.9-2.4	7.3	4.9	2.3	2.1-2.6
2006-11	5927	4816	4880	2749	69,004	52,196	6.1	4.6	1.5	1.3-1.8	6.6	5.0	1.6	1.3-1.9