OPEN ACCESS

Persisting inequalities in birth outcomes related to neighbourhood deprivation

Loes C M Bertens,[1] Lizbeth Burgos Ochoa ,[1] Tom Van Ourti,[2,3] Eric A P Steegers,[1] Jasper V Been[1,4,5]

► Additional material is published online only. To view please visit the journal online (http://dx.doi.org/10.1136/jech-2019-213162).

[1]Department of Obstetrics and Gynaecology, Erasmus MC, University Medical Centre Rotterdam, Rotterdam, The Netherlands
[2]Erasmus School of Economics, University of Rotterdam, Rotterdam, The Netherlands
[3]Tinbergen Institute, Amsterdam, The Netherlands
[4]Division of Neonatology, Department of Paediatrics, Erasmus MC, University Medical Centre Rotterdam, Rotterdam, The Netherlands
[5]Department of Public Health, Erasmus MC, University Medical Centre Rotterdam, Rotterdam, The Netherlands

Correspondence to
Dr Loes C M Bertens, Department of Obstetrics and Gynaecology, Erasmus MC, University Medical Centre Rotterdam, Rotterdam, The Netherlands; l.bertens@erasmusmc.nl

Received 30 August 2019
Revised 14 October 2019
Accepted 19 October 2019

To cite: Bertens LCM, Burgos Ochoa L, Van Ourti T, *et al*. *J Epidemiol Community Health* Epub ahead of print: [*please include* Day Month Year]. doi:10.1136/jech-2019-213162

ABSTRACT

Introduction Health inequalities can be observed in early life as unfavourable birth outcomes. Evidence indicates that neighbourhood socioeconomic circumstances influence health. However, studies looking into temporal trends in inequalities in birth outcomes including neighbourhood socioeconomic conditions are scarce. The aim of this work was to study how inequalities in three different key birth outcomes have changed over time across different strata of neighbourhood deprivation.

Methods Nationwide time trends ecological study with area-level deprivation in quintiles as exposure. The study population consisted of registered singleton births in the Netherlands 2003–2017 between 24 and 41 weeks of gestation. Outcomes used were perinatal mortality, premature birth and small for gestational age (SGA). Absolute rates for all birth outcomes were calculated per deprivation quintile. Time trends in birth outcomes were examined using logistic regression models. To investigate relative inequalities, rate ratios for all outcomes were calculated per deprivation quintile.

Results The prevalence of all unfavourable birth outcomes decreased over time: from 7.2 to 4.1 per 1000 births for perinatal mortality, from 61.8 to 55.6 for premature birth, and from 121.9 to 109.2 for SGA. Inequalities in all birth outcomes have decreased in absolute terms, and the decline was largest in the most deprived quintile. Time trend analyses confirmed the overall decreasing time trends for all outcomes, which were significantly steeper for the most deprived quintile. In relative terms however, inequalities remained fairly constant.

Conclusion In absolute terms, inequalities in birth outcomes by neighbourhood deprivation in the Netherlands decreased between 2003 and 2017. However, relative inequalities remained persistent.

INTRODUCTION

The health of future generations is to a significant degree influenced by parental health around conception and maternal health during pregnancy. Fetal growth and development during pregnancy not only shape the health of the newborn in terms of unfavourable birth outcomes, such as perinatal mortality, premature birth and small for gestational age (SGA) but also health during childhood and in later in life.[1] The global stillbirth rate was estimated in 2016 to be 1.84%, around 2.6 million stillbirths each year. For premature birth, the estimated global rate in 2014 was 10.6%, equating to an estimated 14.8 million premature births.[2] Moreover, it was estimated in 2010 that 32.4 million babies (27.5%) were born SGA worldwide.[3]

Health inequalities are observable differences in health between subgroups of a population.[4 5] These subgroups can be defined by demographic, geographic or socioeconomic factors.[6] Such health inequalities can already be observed during the earliest life stages with unfavourable birth outcomes, which are generally more prevalent among the disadvantaged groups.[7] These groups tend to cluster in deprived neighbourhoods where, next to birth outcomes, growth and development might be negatively influenced.[8]

Despite growing global prosperity and advances in medicine and technology, health inequalities have persisted, and in many cases even widened.[9 10] Reduction of inequalities in health remains a public health policy priority. The discussion on health inequalities has, in recent years, shifted from being held only in the scientific community and policy-making, to being in the general public discussion. For example, recent media coverage on faltering life expectancy in the UK raises the questions of whether and why national austerity measures might be behind a stalling in the improvements in life expectancy and higher child mortality rates—a situation where the most deprived population seems to be the most affected.[11 12] A priority in the study of health inequalities is understanding how they evolve, but current evidence mostly derives from studies with a cross-sectional design, not taking into account the dynamic nature of socioeconomic circumstances. Moreover, most studies focus on mortality and health outcomes in childhood and adulthood,[13–15] with only a few paying attention to birth outcomes.[16–19] Besides, most studies consider only individual-level socioeconomic circumstances,whereas those studies considering neighbourhood (area level) socioeconomic conditions are scarce.

In an egalitarian country like the Netherlands, considerable geographical differences in birth outcomes are present across, between, but also within, delimited areas.[20] In addition, two consecutive perinatal health reports ranked the Netherlands poorly among European countries in terms of overall perinatal mortality,[21 22] followed by a considerable improvement in the latest report.[23] Because of these situations, the Netherlands offers a unique context for the study of trends in health inequalities in birth outcomes.[23] The aim of this work was to study how birth outcomes have evolved differentially by area deprivation level in the Netherlands. Temporal

trends in inequalities in three different key birth outcomes, perinatal mortality, premature birth and SGA, across different strata of neighbourhood deprivation were explored.

METHODS

Data sources

National data on all registered singleton births between 24 and 41 weeks of gestation between 2003 and 2017 were obtained from Perined in October 2018.[24] The Perined registry contains information on >97% of all births in the Netherlands.[24] Pregnancy, delivery and neonatal data are routinely collected by midwives, gynaecologists and paediatricians. A detailed description of the linkage procedures can be found on the Perined website (www.perined.nl).

Outcomes

The following indicators were used to define the birth outcomes: (1) perinatal mortality, defined as intrauterine death occurring after 24 completed weeks of gestational age or neonatal death up to 7 days after birth; (2) premature birth, any birth occurring from 24 weeks of gestational age and before 37 weeks, and (3) SGA birth, birth weight below the 10th centile adjusted for gestational age and sex,[25] according to national reference curves.[26]

Exposure

Deprivation indices calculated by the Netherlands Institute for Health Services Research (NIVEL) were used as an area-level measure of deprivation, each area with an average of 4000 inhabitants. The deprivation index is a (lognormally) standardised population-weighted sum of the proportion of non-active persons (ie, unemployed or not working individuals), mean individual income, mean address density and the proportion of non-western immigrants per neighbourhood.[27] The continuous neighbourhood indices were linked to the individual pregnancies using the registered place of residence at the delivery of the mother. NIVEL calculated the deprivation indices in 2003, 2008 and 2012: the 2003 deprivation index was assigned to all births occurring between 2003 and 2007, the 2008 index was assigned to any birth between 2008 and 2011, and the 2012 deprivation index was used for every birth from 2012 onwards. The deprivation index was categorised into quintiles (from Q1, least deprived, to Q5, most deprived) for each period. As a result, for example, the same deprivation index in 2003 could be classified into a different quintile in 2008. By doing so, differences in the relative distribution of deprivation index between periods were taken into account.

Determinants

The degree of urbanisation was defined as the number of households per km^2 and was categorised into urban (≥2500 households/km^2) and rural (<2500 households/km^2). Maternal characteristics included in the analyses were: maternal age (in years), parity (primiparous vs multiparous) and maternal ethnicity (western vs non-western). In the Perined registry, maternal ethnicity is assigned by the woman's care provider, usually based on appearance, name and information provided.[24]

Missing data

Place of residence of the mother was missing in 0.1% of pregnancies between 2003 and 2017. Also, the deprivation index was not available for neighbourhoods with <200 inhabitants at the time of publication. Accordingly, data on neighbourhood deprivation was missing for 3.2% of the pregnancies. Data on SGA was missing in 0.09% of births due to missing information for birth weight and/or ambiguous child's sex. No data were imputed for the analyses.

Patient involvement

This research was done without patient involvement. Patients were not consulted to develop the research question, nor were they involved in identifying the study design or outcomes. We did not invite any patients to participate in the interpretation of results, nor in the writing or editing of this document. There are no plans to directly involve patients in the dissemination of research findings.

Statistical analyses

Maternal characteristics of all singleton births, as well as birth outcomes, were tabulated by deprivation index quintile and stratified by each period (eg, 2003–2007, 2008–2011 and 2012–2017). Mean absolute perinatal mortality, premature birth and SGA rates per 1000 births were calculated per deprivation quintile per year. The absolute outcome rates were also plotted to visually asses the trends over time.

To further examine time trends in the birth outcomes, individual-level logistic regression models were fitted with the least deprived quintile as a reference group. Log-likelihood ratio tests indicated that natural splines did not improve model fit compared with a linear time trend. Therefore, the linear term was kept for the main analyses. Differential time trends between deprivation quintiles were accounted for by adding the interaction term year*deprivation quintile. Next to the crude models, models accounting for individual-level maternal characteristics (age, ethnicity and parity) were estimated.

Rate ratios for perinatal mortality, premature birth and SGA were calculated for each year and deprivation quintile, with the

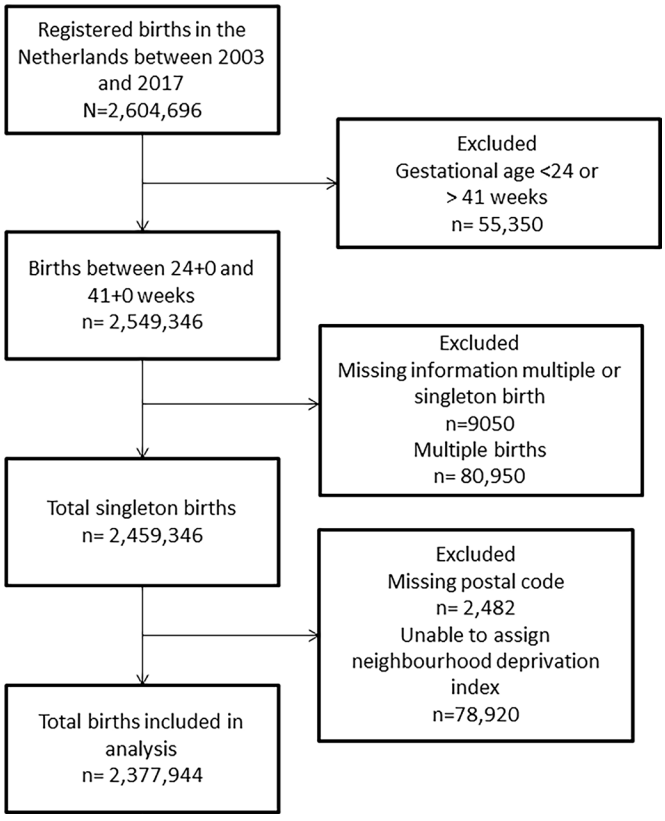

Figure 1 Study population flow diagram.

Table 1 Population characteristics of the singleton pregnancies between 2003 and 2017 by deprivation quintile

	Q1 (Least Deprived), N=478 809	Q2, N=474 282	Q3 N=477 146	Q4, N=473 164	Q5 (Most Deprived) N=474 543	Total, N=2 377 944
Characteristics						
Maternal age*, mean (SD)	**31.1 (4.6)**	**30.9 (4.6)**	**30.7 (4.7)**	**30.2 (5.0)**	**29.7 (5.4)**	**30.5 (4.9)**
2003–2007	31.2 (4.4)	31.0 (4.5)	30.7 (4.7)	30.2 (5.0)	29.2 (5.5)	30.5 (4.9)
2008–2011	31.1 (4.7)	30.8 (4.7)	30.7 (4.8)	30.1 (5.1)	29.7 (5.4)	30.5 (5.0)
2012–2017	30.9 (4.6)	30.9 (4.6)	30.7 (4.7)	30.4 (4.9)	30.1 (5.2)	30.6 (4.8)
Primiparous*, %	**41.7**	**43.5**	**45.7**	**48.2**	**47.1**	**45.2**
2003–2007	41.9	43.9	46.1	49.2	47.7	45.7
2008–2011	41.9	43.8	46.1	49.0	47.8	45.7
2012–2017	41.3	42.8	45.0	46.9	46.2	44.5
Non-Western ethnicity*, %	**5.1**	**7.4**	**11.7**	**17.5**	**40.6**	**16.6**
2003–2007	3.4	5.3	9.6	15.4	40.8	14.5
2008–2011	4.7	7.4	12.3	18.3	41.7	17.0
2012–2017	6.9	9.4	13.2	18.7	39.8	18.1
Urban areas, %	**19.4**	**46.9**	**67.5**	**80.4**	**89.8**	**60.7**
2003–2007	20.1	42.4	63.4	77.7	88.5	57.4
2008–2011	16.0	44.0	70.5	80.0	90.3	60.2
2012–2017	21.3	53.2	69.0	82.8	90.4	63.9
Perinatal outcomes						
Perinatal mortality, %	**0.52**	**0.50**	**0.51**	**0.55**	**0.65**	**0.54**
2003–2007	0.72	0.64	0.66	0.70	0.87	0.72
2008–2011	0.49	0.50	0.51	0.54	0.62	0.53
2012–2017	0.37	0.36	0.38	0.42	0.51	0.41
Premature birth, %	**5.53**	**5.60**	**5.83**	**6.07**	**6.41**	**5.89**
2003–2007	5.80	5.87	6.14	6.26	6.92	6.18
2008–2011	5.67	5.64	5.93	6.30	6.46	6.00
2012–2017	5.19	5.32	5.49	5.75	5.99	5.56
Small for gestational age*, %	**9.39**	**10.10**	**10.92**	**12.19**	**14.52**	**11.42**
2003–2007	10.20	10.76	11.61	13.03	15.83	12.19
2008–2011	9.07	9.96	10.64	12.20	14.11	11.19
2012–2017	8.89	9.59	10.52	11.52	13.82	10.92

Data are presented as numbers and percentages, mean and SD.
Bold numbers refer to values for the full study period (2003-2017).
Total number of registered births per year cohort: 2003-2007, N=791,139 (35.6%); 2008-2011, N=648,535 (29.2%); 2012-2017, N=938,270 (35.3%).
Urban ≥ 2500 households/km^2
*Variable has missing data (maternal age: 0.06%; parity: 0.01%; ethnicity: 0.71%; SGA: 0.09%).

outcome rates in the least deprived quintile used as a base of the ratio. The rate ratios were also plotted to visually asses the trends over time.

To assess the validity of the modelling choices for premature birth and SGA, a sensitivity analysis was performed with only data from livebirths, instead of data from all births. Subgroup analyses were done for: (a) only primiparous women, to control for differences in baseline birth outcome risks vs multiparous women; (b) excluding births between 24 and 26 weeks of gestation, to account for changes in active management of babies at these thresholds over the study period; (c) using very small for gestational age (vSGA, birth weight below 3rd centile) as an outcome; (d) adding the 95th centile as an additional cut-off point within the highest level of deprivation (creating six deprivation categories Q1–Q6), as this cut-off is used by NIVEL to identify deprived neighbourhoods (those in Q6), and provide additional financial fees to midwives caring for women in those areas; and (e) to examine whether neighbourhood deprivation differentials in birth outcomes varied between rural and urban areas, stratified analyses by degree of urbanisation were performed.

For all the analyses an alpha of 0.05 was used as cut-off for statistical significance. All the analyses were performed using R version 3.3.3.[28]

RESULTS

Between 2003 and 2017, 2 459 346 singleton births with a gestational age between 24 and 41 weeks were registered. After excluding all births with missing data on neighbourhood deprivation, 2 377 944 births were available for the analyses (figure 1).

Baseline characteristics of included births are displayed per neighbourhood deprivation quintile in table 1. Maternal characteristics remained stable over time within each deprivation

Table 2 Absolute rates for birth outcomes 2003–2017 per neighbourhood deprivation quintile

Birth outcomes	2003	2008	2012	2017	Change (95% CI)*
Perinatal mortality					
Q1 (least deprived)	7.85	5.37	4.18	3.64	−4.21 (−4.21 to −4.20)
Q2	7.08	5.09	3.92	3.67	−3.41 (−3.41 to −3.40)
Q3	7.99	6.12	3.84	3.94	−4.05 (−4.05 to −4.04)
Q4	7.20	5.79	4.61	3.90	−3.30 (−3.30 to −3.29)
Q5 (most deprived)	9.71	6.65	5.92	4.39	−5.32 (−5.32 to −5.31)
Premature birth					
Q1	57.12	58.95	54.61	50.99	−6.13 (−6.13 to −6.12)
Q2	58.46	55.97	55.26	51.36	−7.10 (−7.10 to −7.09)
Q3	60.20	61.07	56.64	54.32	−5.88 (−5.88 to −5.87)
Q4	61.36	64.18	59.25	56.11	−5.25 (−5.25 to −5.24)
Q5	70.04	66.22	58.80	59.52	−10.52 (−10.52 to −10.51)
SGA					
Q1	104.54	93.56	89.73	88.92	−15.62 (−15.62 to −15.61)
Q2	111.38	97.11	97.10	94.35	−17.03 (−17.03 to −17.02)
Q3	118.27	109.31	104.23	102.95	−15.32 (−15.32 to −15.31)
Q4	133.45	121.80	116.80	112.74	−20.71 (−20.71 to −20.70)
Q5	165.50	143.18	138.06	134.22	−31.28 (−31.28 to −31.27)

Absolute rates presented per 1000 births; rate ratios calculated using least deprived quintile (Q1) as reference category.
*Change is the value of 2017 minus the value of 2003.
CI, 95% confidence interval; SGA, small for gestational age.

quintile. The mean maternal age was 30.5 (SD 4.9), and it was lowest in the most deprived quintile (Q5; 29.7 (SD 5.4)) and highest in the least deprived quintile (Q1; 31.1 (SD 4.6)). The percentage of primiparous women increased with each more deprived quintile (with 47.1% in Q5 compared with 41.7% in Q1). Non-western ethnicity was most prevalent in Q5 (40.6%), and decreased with lower quintiles (from 17.5% in Q4 to 5.1% in Q1). An increase in the prevalence of non-western ethnicity over time was observed. Urban areas were over-represented within levels of deprivation, especially in Q2 to Q5.

Trends in adverse birth outcomes in relation to area deprivation

Absolute rates

The absolute rates (per 1000 births) of each outcome over time are shown in table 2 and figure 2. A steady decline in the prevalence of all outcomes was observed across all levels of deprivation. The absolute decline over time was the largest in the most deprived quintile (Q5) for all birth outcomes, especially between 2003 and 2008. For example, premature birth rates decreased by 6.1 per 1000 births in the least deprived quintile and by 10.5 per 1000 births in the most deprived quintile.

Time trend analyses

Time trend analyses were performed to test the observed differences in trends between quintiles, also when adjusted for maternal age, ethnicity and parity (table 3). The coefficients for intercept and slope from the estimated models are in line with the observed patterns; significant differences between deprivation quintiles in baseline outcome rates were present, whereas a significant decreasing overall time trend was present across all deprivation quintiles. However, time trends across neighbourhood deprivation quintiles, assessed using the interaction term year*deprivation quintile, indicated significantly steeper decreasing trends for premature births and SGA in Q5 compared with Q1, but not for perinatal mortality. The other quintiles (Q2–Q4) did not differ significantly from Q1 regarding their time trends.

Relative rates

Rate ratios (RRs) were calculated across the observation period for each outcome using the least deprived quintile (Q1) as base. These RRs provide information on the birth outcome rates per year in Q2–Q5 relative to the birth outcome rate in Q1 in the same year. Table 4 and figure 3 show the RRs for perinatal mortality, premature birth and SGA over time. The RRs show a social gradient similar to that seen in the absolute outcome rates, however contrary to the absolute rates, these RRs did not materially change between 2003 and 2017.

Sensitivity analyses

The findings from the sensitivity and subgroup analyses are summarised in the online supplementary tables a–f. Overall, findings from the subgroup analyses were in line with the findings from the main analyses. Results from subgroup analysis (e), in which an additional cut-off was introduced to delineate the 5% most deprived areas, indicated that the association between area-level deprivation and adverse birth outcomes was particularly concentrated in the most deprived areas. The trend analyses with the additional cut-off showed similar results to the main analyses, indicating significantly steeper decreasing trends for premature births and SGA in Q6 compared with Q1. Analyses stratified by level of urbanisation (f) indicated that the association between neighbourhood deprivation and adverse birth outcomes was present in urbanised areas and not so much in rural areas. Furthermore, results from the time-trend analyses for urban areas also showed steeper decreasing trends for premature births and SGA in Q5 compared with Q1; however, for rural areas, no significant increasing or decreasing trends were found for any of the three birth outcomes.

Figure 2 Prevalence (per 1000 births) of perinatal mortality, premature birth and SGA by neighbourhood deprivation quintile (2003–2017). SGA, small for gestational age.

DISCUSSION

In the Netherlands, between 2003 and 2017, the prevalence of perinatal mortality, premature birth and SGA consistently decreased over time in all area deprivation quintiles, being the most deprived areas the ones showing the largest improvements. Although absolute inequalities in these outcomes decreased over time, relative inequalities in birth outcomes by neighbourhood deprivation level remained fairly constant.

A major strength of this study is its longitudinal approach, which allows observing time trend differences in birth outcomes. Another strength is the amount of data available for the analyses; the dataset was drawn from a national-level registry over a long period 2003–2017, covering >97% of all births in the Netherlands, resulting in over 2.3 million records available for analysis. The dynamic nature of neighbourhood deprivation was taken into account as the index was updated over the study period. This is important as most previous studies only used a single cross-sectional measure of neighbourhood deprivation for the entire period.[29 30] Our finding of declining absolute but persisting relative inequalities confirmed that considering absolute and relative measures of health inequalities is necessary and provides complementary information. A limitation is that certain factors that are more prevalent among residents of deprived neighbourhoods and that could account for part of the observed variability (eg, overweight and maternal smoking)[31] were not available in the dataset. Another limitation is that not all births in the dataset could be linked to a deprivation index, mainly due to the deprivation index not being available for areas with <200 inhabitants or a missing place of residence of the mother, but the impact is likely small as only 3.2% of all births had a relevant data item missing.

A decrease in the overall prevalence of unfavourable birth outcomes in the Netherlands is consistent with the findings of European reports.[23 32] The overall decreasing trend and the reduction of absolute inequalities could partly be explained by changes in the organisation of preconceptional, antenatal and postnatal care and public health actions.[33] Apart from strategies to improve birth outcomes in the general population, policies targeting the most deprived sectors of the population were also made available in this period. Also, multiple intervention programmes to improve perinatal health were launched with a general focus on vulnerable populations.[34 35] As found in previous studies,[36] maternal smoking is an important contributor to inequalities in birth outcomes. It is possible that the reduction in absolute inequalities may in part have been affected by changes in tobacco control policies and decreasing smoking rates.[37]

Table 3 Beta coefficients (95% CI) from logistic regressions for time trend analysis of unfavourable birth outcomes by neighbourhood deprivation quintile, the Netherlands 2003–2017

Variables	Perinatal mortality		Premature birth		SGA	
	Crude	Adjusted‡	Crude	Adjusted‡	Crude	Adjusted‡
Year†	−0.0003 (0.0003 to −0.0010)*	−0.0003 (−0.0003 to −0.0003)*	−0.0006 (−0.0008 to −0.0004)*	−0.0006 (−0.0008 to −0.0004)*	−0.0013 (−0.0015 to −0.0011)*	−0.0014 (−0.0016 to −0.0012)*
Neighbourhood deprivation quintile†						
Q1 (least deprived)	REF	REF	REF	REF	REF	REF
Q2	−0.0006 (−0.0012 to 0.0001)*	−0.0007 (−0.0013 to −0.0001)*	0.0003 (−0.0015 to 0.0021)	−0.0003 (−0.0021 to 0.0015)	0.0063 (0.0039 to 0.0087)*	0.004 (0.0016 to 0.0064)*
Q3	−0.0004 (−0.0001 to 0.0002)	−0.0006 (−0.0012 to 0.0001)*	0.0031 (0.0013 to 0.0049)*	0.0016 (−0.0002 to 0.0034)	0.0141 (0.0117 to 0.0165)*	0.0083 (0.0059 to 0.0107)*
Q4	−0.0002 (−0.0008 to 0.0004)	−0.0005 (−0.0011 to 0.0001)	0.0051 (0.0033 to 0.0069)*	0.0023 (0.0005 to 0.0041)*	0.0298 (0.0274 to 0.0322)*	0.0188 (0.0164 to 0.0212)*
Q5 (most deprived)	0.0017 (0.0011 to 0.0023)*	0.0008 (0.0002 to 0.0014)*	0.0110 (0.0092 to 0.0128)*	0.0076 (0.0058 to 0.0094)*	0.0565 (0.0541 to 0.0589)*	0.0345 (0.0320 to 0.0370)*
Interaction deprivation quintile* year†						
Q1 (least deprived)	REF	REF	REF	REF	REF	REF
Q2	0.0001 (0.0000 to 0.0002)	0.0001 (0.0000 to 0.0002)	0.0001 (−0.0001 to 0.0003)	0.0000 (−0.0002 to 0.0002)	0.0001 (−0.0002 to 0.0004)	0.0001 (−0.0002 to 0.0004)
Q3	0.0000 (−0.0001 to 0.0001)	0.0000 (−0.0001 to 0.0001)	0.0000 (−0.0002 to 0.0002)	0.0000 (−0.0002 to 0.0002)	0.0002 (−0.0001 to 0.0005)	0.0002 (−0.0001 to 0.0005)
Q4	0.0001 (0.0001 to 0.0002)*	0.0001 (0.0000 to 0.0002)	0.0001 (−0.0001 to 0.0003)	0.0001 (−0.0001 to 0.0003)	−0.0002 (−0.0005 to 0.0001)	−0.0001 (−0.0004 to 0.0002)
Q5 (most deprived)	0.0000 (−0.0001 to 0.0001)	−0.0001 (−0.0002 to 0.0000)	−0.0003 (−0.0005 to −0.0001)*	−0.0004 (−0.0006 to −0.0002)*	−0.0007 (−0.001 to −0.0004)*	−0.0004 (−0.0007 to −0.0001)*

* p<0.05.
†Results from models with linear trend for year.
‡Adjusted for ethnicity, maternal age and parity.
CI, 95% confidence interval; SGA, small for gestational age.

Studies looking into trends in health inequalities in birth outcomes using area-level deprivation are rather rare.[17 19] The results from the present study are in line with previous studies in the field of health inequalities, while adding to the literature in multiple ways. In the current study, the absolute rates and RRs showed a social gradient, where the largest inequalities were observed between the most and the least deprived quintiles. Furthermore, the social gradient in relative terms remained persistent over the study period. These results are similar to what was found by Gray *et al* in Scotland,[17] however, their study focused on premature birth, in contrast, the present study also includes perinatal mortality and SGA as outcomes. As in the study by Luo *et al*,[19] conducted in the Canadian province of British Columbia, the largest inequalities in the present study were observed in urbanised neighbourhoods, however, this paper has the added value of using a nationwide population database. An explanation for these results could be that residents of deprived neighbourhoods in urbanised areas have higher exposure to social and environmental risk factors for unfavourable birth outcomes, such as air pollution, ambient noise, higher temperatures and stress.[38] Alternatively, stronger inequalities in urbanised areas may be found due to the calculation method of the NIVEL deprivation index. The index includes address density, where higher density values have a higher contribution to the index and vice versa.[27 39] This feature might make the index less sensitive to displaying disadvantage in low urbanised areas as the variation in address density is likely lower in rural areas and its contribution to inequalities smaller. Additionally, some authors have argued that existing deprivation indexes mostly take into account characteristics of urban settings that may be less relevant in capturing rural deprivation.[40 41] A particular difference, and asset, of the present study compared with previous research is the context of overall substantial improvement in birth outcomes in the Netherlands during the study period. The results of this study are remarkable as they show that even in the context of such large overall improvements, where these have permeated in absolute terms across all deprivation levels, relative inequalities have still remained persistent over time.

The present study aimed to describe trends in health inequalities in birth outcomes in the Netherlands to provide insight and aid in the formulation of hypotheses for future, potentially, research on the underlying mechanisms, instead of focusing on finding casual associations. Further research is necessary to explore the underlying mechanisms for the likely causal effects of neighbourhood deprivation on birth outcomes.

The main findings indicate that there is still work to be done to reduce inequalities in birth outcomes between more and less deprived neighbourhoods in the Netherlands. Apart from the general importance of promoting health across all age groups, the reduction of inequalities in birth outcomes is especially important because of evidence linking early life conditions to long-term health and social functioning. Long-term health outcomes could be jeopardised not only by unfavourable birth outcomes but also due to the additional effect of growing up in a disadvantaged neighbourhood. Moreover, the association between neighbourhood deprivation and birth outcomes could be an important channel explaining how poor health and social performance prevail across generations.[42]

In conclusion, although absolute inequalities in adverse birth outcomes in the Netherlands have been narrowing over time, relative inequalities remained persistent over the observed period. These findings provide support for continuing public health actions to reduce these inequalities and advancing research efforts to explore the underlying mechanisms of neighbourhood effects on health outcomes.

Table 4 Rate ratios (95% CI) for birth outcomes 2003–2017 per neighbourhood deprivation quintile

Birth outcomes	2003	2008	2012	2017	Change (95% CI)*
Perinatal mortality					
Q1 (least deprived)	REF	REF	REF	REF	REF
Q2	0.91 (0.87 to 0.93)	0.95 (0.90 to 0.98)	0.94 (0.89 to 0.97)	1.01 (0.96 to 1.05)	0.10 (0.09 to 0.10)
Q3	1.02 (0.98 to 1.05)	1.15 (1.09 to 1.18)	0.92 (0.88 to 0.95)	1.09 (1.03 to 1.12)	0.07 (0.06 to 0.07)
Q4	0.92 (0.88 to 0.95)	1.08 (1.03 to 1.12)	1.11 (1.06 to 1.14)	1.08 (1.03 to 1.11)	0.16 (0.15 to 0.17)
Q5 (most deprived)	1.24 (1.19 to 1.27)	1.24 (1.19 to 1.28)	1.42 (1.36 to 1.46)	1.21 (1.15 to 1.25)	−0.03 (−0.03 to −0.05)
Premature birth					
Q1	REF	REF	REF	REF	REF
Q2	1.02 (1.01 to 1.03)	0.94 (0.93 to 0.96)	1.01 (0.99 to 1.02)	1.01 (0.99 to 1.02)	−0.01 (−0.01 to −0.01)
Q3	1.05 (1.04 to 1.06)	1.03 (1.02 to 1.05)	1.03 (1.02 to 1.05)	1.06 (1.05 to 1.07)	0.01 (0.01 to 0.01)
Q4	1.07 (1.06 to 1.08)	1.08 (1.07 to 1.1)	1.08 (1.07 to 1.09)	1.10 (1.08 to 1.11)	0.04 (0.03 to 0.04)
Q5	1.22 (1.21 to 1.24)	1.12 (1.10 to 1.13)	1.07 (1.06 to 1.09)	1.16 (1.15 to 1.18)	−0.06 (−0.06 to −0.05)
SGA					
Q1	REF	REF	REF	REF	REF
Q2	1.06 (1.05 to 1.07)	1.03 (1.02 to 1.04)	1.08 (1.07 to 1.09)	1.07 (1.05 to 1.07)	0.01 (0.01 to 0.01)
Q3	1.13 (1.12 to 1.14)	1.16 (1.15 to 1.18)	1.16 (1.15 to 1.17)	1.15 (1.14 to 1.16)	0.02 (0.01 to 0.02)
Q4	1.27 (1.26 to 1.28)	1.30 (1.28 to 1.31)	1.30 (1.28 to 1.31)	1.26 (1.25 to 1.27)	−0.01 (−0.01 to −0.01)
Q5	1.58 (1.56 to 1.59)	1.53 (1.51 to 1.54)	1.53 (1.52 to 1.55)	1.51 (1.49 to 1.52)	−0.07 (−0.07 to −0.06)

Absolute rates presented per 1000 births; rate ratios calculated using least deprived quintile (Q1) as reference category.
*Change is the value of 2017 minus the value of 2003.
CI, 95% confidence interval; SGA, small for gestational age.

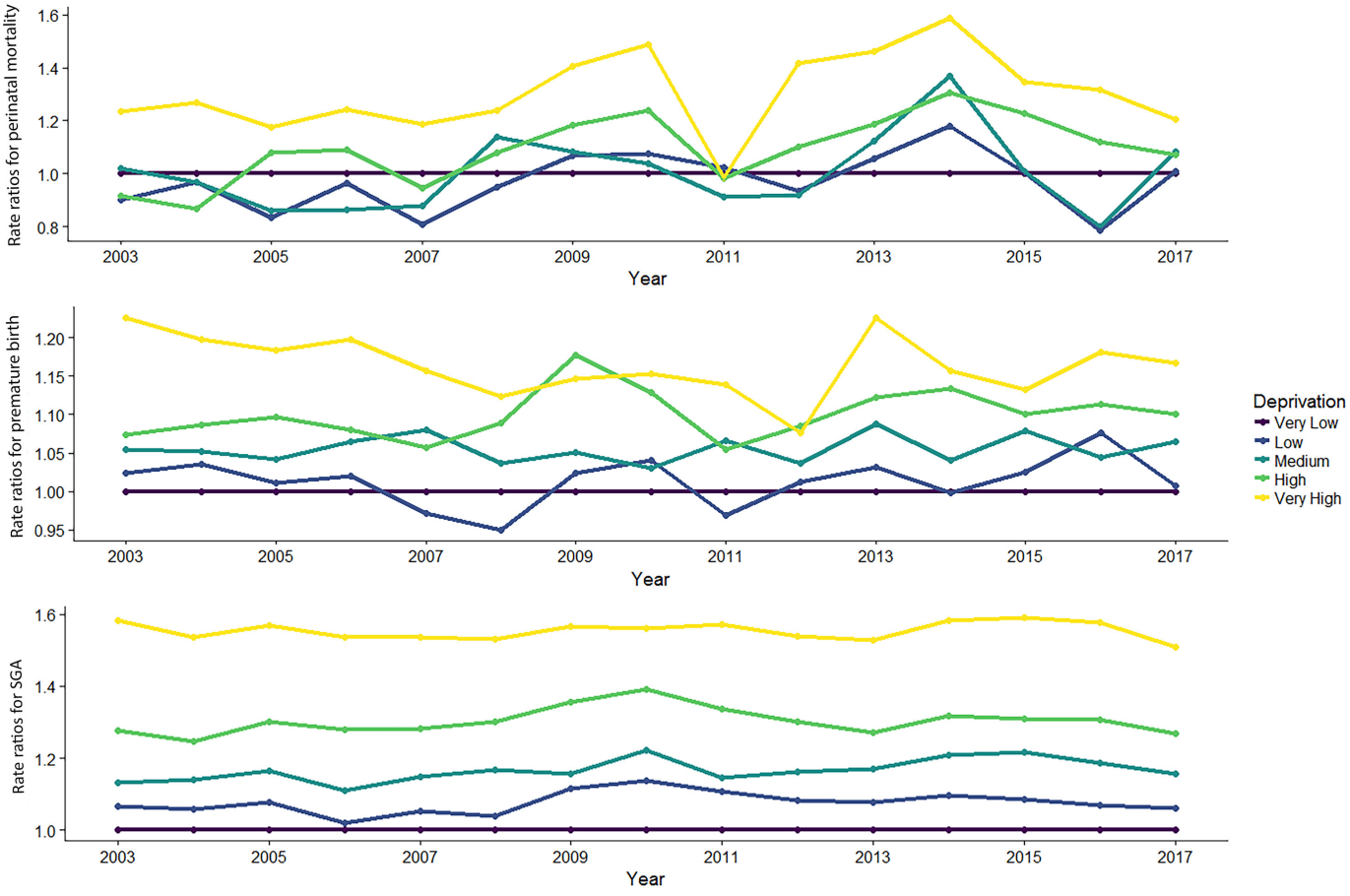

Figure 3 Rate ratios for perinatal mortality, premature birth and SGA by neighbourhood deprivation quintile (least deprived quintile used as reference category) 2003–2017. SGA, small for gestational age.

What is already known on this subject

- Health inequalities can be observed since early life in form of unfavourable birth outcomes.
- Living in a disadvantaged neighbourhood has been associated with higher risk of unfavourable birth outcomes.

What this study adds

- This study found that in the Netherlands absolute inequalities in perinatal mortality, premature birth and small for gestational age decreased over time, and steeper decreasing trends were observed for the most deprived quintile.
- Despite the improvement in absolute terms, relative inequalities in birth outcomes by neighbourhood deprivation level remained fairly constant over time.

Contributors LCMB, TVO and JVB: conceived the study. All authors participated in its design. LCMB did the statistical analysis; had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis; is the guarantor. All authors were involved in interpreting the findings. LBO and LCMB: drafted the manuscript. All authors reviewed, edited, and approved the final manuscript.

Funding This study was funded by the Erasmus Initiative Smarter Choices for Better Health.

Competing interests None declared.

Patient consent for publication Not required.

Ethics approval This study was approved by Perined, no further ethical approval was needed.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. However, access may be granted upon request following the procedure available at https://www.perined.nl/.

ORCID iD

Lizbeth Burgos Ochoa http://orcid.org/0000-0002-8379-2749

REFERENCES

1 Barker DJP, Eriksson JG, Forsén T, *et al*. Fetal origins of adult disease: strength of effects and biological basis. *Int J Epidemiol* 2002;31:1235–9.
2 Chawanpaiboon S, Vogel JP, Moller A-B, *et al*. Global, regional, and national estimates of levels of preterm birth in 2014: a systematic review and modelling analysis. *Lancet Glob Health* 2019;7:e37–46.
3 Black RE. Global prevalence of small for gestational age births. In: *Low-Birthweight baby: born too soon or too small*. Karger Publishers, 2015: 1–7.
4 World Health Organization Commission on the Social Determinants of Health. Closing the gap: policy into practice on social determinants of health: discussion paper 2011.
5 Krieger N, Waterman PD, Spasojevic J, *et al*. Public health monitoring of privilege and deprivation with the index of concentration at the extremes. *Am J Public Health* 2016;106:256–63.
6 World Health Organization. *State of Inequality: Reproductive Maternal Newborn and Child Health: Interactive Visualization of Health Data*. World Health Organization, 2015.
7 Blumenshine P, Egerter S, Barclay CJ, *et al*. Socioeconomic disparities in adverse birth outcomes: a systematic review. *Am J Prev Med* 2010;39:263–72.
8 de Graaf JP, Ravelli ACJ, de Haan MAM, *et al*. Living in deprived urban districts increases perinatal health inequalities. *J Matern Fetal Neonatal Med* 2013;26:473–81.
9 Chetty R, Stepner M, Abraham S, *et al*. The association between income and life expectancy in the United States, 2001-2014. *JAMA* 2016;315:1750–66.
10 van Kippersluis H, O'Donnell O, van Doorslaer E, *et al*. Socioeconomic differences in health over the life cycle in an egalitarian country. *Soc Sci Med* 2010;70:428–38.
11 Mckie R. Why is life expectancy faltering? The guardian 2019.
12 Matthews-King A. Infant mortality rates rise for third consecutive year, hitting poorest communities hardest. *The Independent* 2019.
13 Elgar FJ, Pförtner T-K, Moor I, *et al*. Socioeconomic inequalities in adolescent health 2002–2010: a time-series analysis of 34 countries participating in the health behaviour in school-aged children study. *The Lancet* 2015;385:2088–95.
14 Hartley A, Marshall DC, Salciccioli JD, *et al*. Trends in mortality from ischemic heart disease and cerebrovascular disease in Europe. *Circulation* 2016;133:1916–26.
15 Mackenbach JP, Hu Y, Artnik B, *et al*. Trends in inequalities in mortality amenable to health care in 17 European countries. *Health Aff* 2017;36:1110–8.
16 Gissler M, Rahkonen O, Arntzen A, *et al*. Trends in socioeconomic differences in Finnish perinatal health 1991-2006. *J Epidemiol Community Health* 2009;63:420–5.
17 Gray R, Bonellie SR, Chalmers J, *et al*. Social inequalities in preterm birth in Scotland 1980-2003: findings from an area-based measure of deprivation. *BJOG* 2008;115:82–90.
18 Kent ST, McClure LA, Zaitchik BF, *et al*. Area-level risk factors for adverse birth outcomes: trends in urban and rural settings. *BMC Pregnancy Childbirth* 2013;13:129.
19 Luo Z-C, Kierans WJ, Wilkins R, *et al*. Disparities in birth outcomes by neighborhood income: temporal trends in rural and urban areas, British Columbia. *Epidemiology* 2004:679–86.
20 Vos AA, Denktaş S, Borsboom GJJM, *et al*. Differences in perinatal morbidity and mortality on the neighbourhood level in Dutch municipalities: a population based cohort study. *BMC Pregnancy Childbirth* 2015;15:201.
21 EURO-PERISTAT project in collaboration with SCPE EUROCAT and EURONEOSTAT. Better statistics for better health for pregnant women and their babies in 2004 2008.
22 Zeitlin J, Wildman K, Bréart G, *et al*. PERISTAT: indicators for monitoring and evaluating perinatal health in Europe. *Eur J Public Health* 2003;13:29–37.
23 Zeitlin J, Mortensen L, Cuttini M, *et al*. Declines in stillbirth and neonatal mortality rates in Europe between 2004 and 2010: results from the Euro-Peristat project. *J Epidemiol Community Health* 2016;70:609–15.
24 Perined. Perinatal care in the Netherlands 2014. Utrecht 2015.
25 Hoftiezer L, Hukkelhoven CWPM, Hogeveen M, *et al*. Defining small-for-gestational-age: prescriptive versus descriptive birthweight standards. *Eur J Pediatr* 2016;175:1047–57.
26 Hoftiezer L, Hof MHP, Dijs-Elsinga J, *et al*. From population reference to national standard: new and improved birthweight charts. *Am J Obstet Gynecol* 2019;220:383.e1
27 Devillé W, Wiegers TA. Herijking stedelijke achterstandsgebieden 2012: NIVEL 2012.
28 R: A language and environment for statistical computing [program]. Vienna, Austria: R Foundation for Statistical Computing 2017.
29 McCartney D, Scarborough P, Webster P, *et al*. Trends in social inequalities for premature coronary heart disease mortality in Great Britain, 1994–2008: a time trend ecological study. *BMJ Open* 2012;2:e000737.
30 Tromp M, Eskes M, Reitsma JB, *et al*. Regional perinatal mortality differences in the Netherlands; care is the question. *BMC Public Health* 2009;9:102.
31 Sellström E, Arnoldsson G, Bremberg S, *et al*. The neighbourhood they live in—Does it matter to women's smoking habits during pregnancy? *Health Place* 2008;14:155–66.
32 Zeitlin J, Szamotulska K, Drewniak N, *et al*. Preterm birth time trends in Europe: a study of 19 countries. *BJOG: Int J Obstet Gy* 2013;120:1356–65.
33 Vos AA, van Voorst SF, Steegers EAP, *et al*. Analysis of policy towards improvement of perinatal mortality in the Netherlands (2004–2011). *Soc Sci Med* 2016;157:156–64.
34 Denktaş S, Poeran J, van Voorst SF, *et al*. Design and outline of the healthy pregnancy 4 all study. *BMC Pregnancy Childbirth* 2014;14:253.
35 Waelput AJM, Sijpkens MK, Lagendijk J, *et al*. Geographical differences in perinatal health and child welfare in the Netherlands: rationale for the healthy pregnancy 4 all-2 program. *BMC Pregnancy Childbirth* 2017;17:254.
36 Gray R, Bonellie SR, Chalmers J, *et al*. Contribution of smoking during pregnancy to inequalities in stillbirth and infant death in Scotland 1994-2003: retrospective population based study using Hospital maternity records. *BMJ* 2009;339:b3754.
37 Peelen MJ, Sheikh A, Kok M, *et al*. Tobacco control policies and perinatal health: a national quasi-experimental study. *Sci Rep* 2016;6:23907.
38 Smith RB, Fecht D, Gulliver J, *et al*. Impact of London's road traffic air and noise pollution on birth weight: retrospective population based cohort study. *BMJ* 2017;359.
39 Devillé W, Verheij RA, de Bakker DH. Herijking stedelijke achterstandsgebieden 2003: NIVEL 2003.
40 Burke A, Jones A. The development of an index of rural deprivation: a case study of Norfolk, England. *Soc Sci Med* 2019;227:93–103.
41 Fecht D, Jones A, Hill T, *et al*. Inequalities in rural communities: adapting national deprivation indices for rural settings. *J Public Health* 2018;40:419–25.
42 Wickrama KAS, Conger RD, Abraham WT. Early adversity and later health: the intergenerational transmission of adversity through mental disorder and physical illness. *The Journals of Gerontology: Series B* 2005;60:S125–9.