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Dutch nationwide registry study to identify spatial, contextual and environmental inequalities in birth outcomes

Anna J Suleri ,[1] Loes C M Bertens,[1] Istiaque Ahmed,[2] Medha Pfaff,[1] Frank van der Hoeven ,[2] Eric A P Steegers ,[1] Jasper V Been[1,3]

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[1]Obstetrics and Gynecology, Erasmus MC University Medical Center, Rotterdam, Netherlands
[2]Department of Architecture, TU Delft, Delft, Netherlands
[3]Neonatal and Paediatric Intensive Care, Erasmus MC University Medical Center, Rotterdam, Netherlands

Correspondence to
Dr Anna J Suleri; a.suleri@erasmusmc.nl

ABSTRACT

Introduction The first 1000 days of life, from conception to age 2, are crucial for a child's development, with lasting health impacts. Evidence is growing that environmental and social factors, especially the neighbourhood of birth, play a significant role in shaping health during this period. This study investigates perinatal health disparities in 20 high-risk Dutch neighbourhoods identified by the governmental National Program on Livability and Safety and outlines an initiative to develop tools aimed at reducing geographical health inequalities and improving birth outcomes.

Methods Using data from the national perinatal registry (Perined) from 2015 to 2021, we analysed perinatal outcomes in 1 118 022 mother–child pairs, including perinatal mortality (24 weeks gestation to 7 days postbirth), small for gestational age (SGA; birthweight <10th percentile, corrected for gestational age and sex) and preterm birth (<37 weeks). Three-step logistic regression compared outcomes across all high-risk areas versus the rest of the country, each high-risk area versus national levels and each area versus its municipality, adjusting for confounders and multiple testing.

Results We observed that SGA (OR 1.19 (95% CI 1.16 to 1.21)), preterm birth (OR 1.09 (95% CI 1.06 to 1.12)) and perinatal mortality (OR 1.13 (95% CI 1.02 to 1.24)) were significantly higher within high-risk areas compared with the rest of the Netherlands. These disparities persisted across the various comparisons.

Conclusion Living in high-risk neighbourhoods, as defined by livability and safety parameters, is linked to adverse birth outcomes, underscoring the need for targeted, location-based policies. Our collaborative initiative aims to co-develop a knowledge agenda with key stakeholders to create actionable tools that reduce health inequalities from birth.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Perinatal outcomes are influenced not only by biological and individual factors, but also by broader environmental and social determinants, including neighbourhood conditions. However, the impact of living in specific high-risk neighbourhoods, defined by safety and livability metrics, on perinatal health, compared with living in other areas of the Netherlands, has not been systematically assessed.

WHAT THIS STUDY ADDS

⇒ This study shows that perinatal mortality, preterm birth and small for gestational age are all significantly more common in Dutch high-risk neighbourhoods, even after adjusting for confounders. These disparities persist both compared with national averages and to the rest of the municipality.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our findings underscore the importance of geographically targeted interventions and policies to improve perinatal health. The results support the development of place-based tools and interdepartmental collaborations ('health in all policies') to reduce early-life health inequalities through evidence-informed action.

INTRODUCTION

The first 1000 days of life, spanning from conception to a child's second birthday, represent a critical window for growth and development, with lifelong implications for health and well-being.[1] While extensive research has explored the role of biological and medical factors in shaping perinatal outcomes,[2] growing evidence indicates that broader societal and environmental exposures also play a crucial role.[3–7] All environmental exposures an individual encounters throughout life, whether outdoor, indoor, medical or contextual, are collectively referred to as the exposome. Examples include air pollution, noise, neighbourhood socioeconomic status, social interactions, housing conditions and indoor air quality. These factors can contribute to disparities in birth outcomes,[3–8] yet their relative contributions remain poorly understood.

A key determinant of the exposome is the neighbourhood where a mother resides before and during pregnancy and where the child is born into.[9–12] Geographical differences in environmental conditions, socioeconomic status and infrastructure can lead to spatial inequalities in birth outcomes.[3–7 12] Despite increasing global wealth and progress in medicine and technology, health disparities have persisted, and in some instances, even worsened.[13 14] Certain neighbourhoods expose pregnant individuals and newborns to higher levels of environmental stressors, potentially increasing the risk of adverse health effects.[9–11] Previous literature has shown that birth outcomes were worse in neighbourhoods with lower socioeconomic status. As these neighbourhoods improved over time, so did the birth outcomes, indicating that addressing negative environmental influences can benefit perinatal health.[15] The extent to which these disparities can be addressed through policy interventions is still uncertain but reducing these inequalities is a key priority in public health policy.

In 2022, the Dutch National Program on Livability and Safety (NLPV) was launched by National Ministry of the Interior and Kingdom Relations to improve safety and livability in vulnerable neighbourhoods across the Netherlands. The program identified 20 high-risk neighbourhood areas for targeted policy implementation over a 15-year period, selected based on characteristics related to their physical environment and safety. As part of this programme, a collaborative project was launched between policymakers (Ministries of Health, Welfare and Sports, Social Affairs and Employment, and Interior and Kingdom Relations) and scientists (Erasmus MC, TU Delft) to address knowledge gaps in the literature on the relationship between the direct living environment and perinatal health. Understanding and addressing these factors align with the 'Health in All Policies' approach, emphasising that health is shaped by policies across various sectors beyond healthcare alone. This approach has also been highlighted by our own government as well as by the WHO.[16 17] The goal is to develop tangible recommendations for Dutch policy, based on investigation of the factors underlying maternal and child health in the 20 high-risk areas in the first 1000 days. Specifically, the main objective of our initiative is to examine how outdoor exposome factors during the preconception and conception phases influence perinatal health outcomes. Our secondary aim is to investigate the impact of indoor exposome factors during the same critical period, depending on data availability. Finally, we will explore potential interactions between indoor and outdoor exposures to gain a more comprehensive understanding of their combined influence on perinatal health (figure 1). Ultimately, our goal is to identify modifiable contextual and environmental determinants that contribute most significantly to adverse perinatal health, providing actionable insights for policymakers. To achieve this, we will link and analyse data from multiple large-scale datasets, such as Statistics Netherlands data and perinatal registration data (Perined) in the Netherlands.[18 19]

Hence, the current paper serves as the design framework of our research initiative. In this paper, we focus on spatial, contextual and environmental inequalities in birth outcomes, analysing differences in perinatal health across designated NPLV high-risk areas in the Netherlands. By examining whether birth outcomes vary across these regions, we aim to provide empirical evidence to

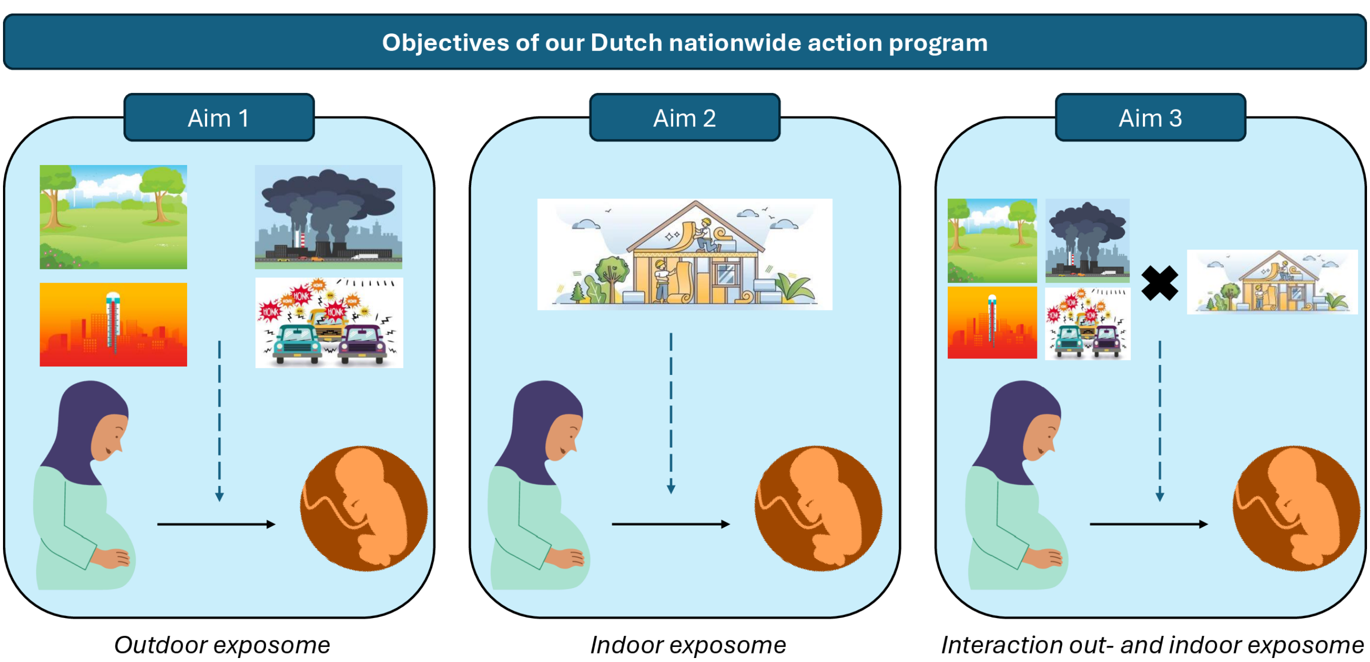

Figure 1 Three objectives of our Dutch nationwide action programme to investigate the association between the outdoor and indoor exposome on birth outcomes.

inform targeted policy interventions that can reduce health disparities from the earliest stages of life.

METHODS

Study population

We utilised nationwide perinatal registry data from Perined of pregnancies with births registered between 2015 and 2021.[18] Our study included all registered viable singleton pregnancies from 24 weeks of gestation onward. This registry compiles data from community midwives, gynaecologists and paediatricians, covering pregnancy, delivery and neonatal outcomes. The Perined registry encompasses information on over 97% of all births in the Netherlands. A detailed description of the linkage procedures is available on the Perined website (www.perined.nl).

Exposure

The primary exposure in this study was residence in a designated high-risk area—one of 20 neighbourhoods identified by the Dutch National Program on Liveability and Safety (see online supplemental text A). These high-risk areas are located across 19 municipalities (online supplemental table S1) and represent vulnerable urban areas where citizens struggle with a combination of socioeconomic problems such as unemployment, poverty, educational disadvantage, housing problems, safety problems and poor health. The Netherlands was divided into 40 areas, comprising the 20 designated high-risk areas, the 19 municipalities containing these high-risk areas (ie, two high-risk areas were located in the same city) and the remainder of the country (online supplemental figure S1). Residential postal codes of pregnant individuals were used to determine high-risk area residency.

Outcomes

Three perinatal health outcomes were examined in this study. Perinatal mortality was defined as death occurring from 24 weeks of pregnancy, during delivery, or within the first 7 days after birth. Small for gestational age (SGA) was defined as a birth weight below the 10th percentile, adjusted for gestational age and fetal sex, according to national reference curves.[20] Preterm birth was classified as any birth, including stillbirths, occurring before 37 completed weeks of gestation.

Missing data

Cases with missing data in covariates or outcome were excluded, with a maximum missingness of 2.7% per variable, which was highest for maternal migration background. For the other covariates and for the outcome SGA, the missingness was 1.5%–2%. There was no missing data for the outcomes preterm birth or perinatal mortality.

Statistical analyses

Prevalence rates per 1000 births were calculated for each of the three perinatal health outcomes across the high-risk areas. Geographic variations in prevalence rates were visualised using the program QGIS (V.3.40 Bratislava).

To assess differences in perinatal health outcomes between high-risk areas and other regions in the Netherlands, a hierarchical three-step approach was conducted using logistic regression models. First, residing in a high-risk area (all 20 combined; yes/no) was compared with living outside these areas. Second, each individual high-risk area was compared with the rest of the Netherlands, treating high-risk areas as a categorical variable. Finally, each high-risk area was directly compared with the rest of the municipality (minus the high-risk area itself) it belongs to. Odds Ratios (ORs) and corresponding 95% Confidence Intervals (CIs) were calculated.

All models were adjusted for the following covariates: maternal age (years), parity (categorical: nullipara vs multipara), and migration background (Dutch vs non-Dutch). Of note, migration background was derived from the Perined database, where it was recorded based on the obstetric professional's impression, judgement or inquiry. To improve reliability of this variable, we reclassified it into a binary indicator distinguishing between 'Dutch' and 'non-Dutch'. A correlation matrix of all included variables is found in online supplemental figure S2. We applied the Galway correction to account for multiple testing. With three outcomes, the effective number of tests was determined to be 3, which led to a corrected significance threshold of p=0.017 (instead of 0.05).[21] All statistical analyses were performed with R statistical software (V.4.1.0; R Development Core Team).[22] This manuscript was prepared in accordance with the REporting of studies Conducted using Observational Routinely-collected Data (RECORD) checklist (online supplemental text B).

Patient and Public involvement

This paper is part of a larger initiative, initiated by the Erasmus MC and TU Delft in collaboration with the Ministries of Health, Welfare and Sports, Social Affairs and Employment, and Interior and Kingdom Relations. It is embedded within the national Solid Start program ((https://www.kansrijkestart-ppp.nl), in which patient and public representatives have an active role. For the present manuscript, no patients or members of the public were involved. The findings will be disseminated to the public alongside future outputs from this initiative.

RESULTS

Between 2015 and 2021, a total of 1 166 958 pregnancies were registered. Among these, 1 156 200 pregnancies were potentially viable, and 1 153 180 had a gestational age of more than 24 weeks. After excluding multiple pregnancies, the final sample for analysis comprised 1 118 022 mother-child pairs (online supplemental figure S3). The baseline characteristics of the participants are represented in table 1. The overall prevalence of

Table 1 Baseline characteristics between 2015 and 2021 for the high-risk areas and the rest of the Netherlands

	Total Netherlands	High-risk areas	Rest of the Netherlands
	(n=1 118 022)	(n=99 757)	(n=1 018 265)
Maternal variables			
Maternal age (years)			
Mean (SD)	30.86 (4.7)	30.32 (5.1)	30.91 (4.7)
Missing	2539	76	2463
Parity			
1	493 701	43 497	450 204
2	169 208	32 962	136 246
3+	452 182	23 157	429 025
Missing	2931	141	2790
Ethnicity			
Dutch	862 248	47 429	814 819
Other	240 203	51 246	188 957
Missing	30 530	3255	27 275
Birth outcomes			
Perinatal mortality			
Yes	4595	528	4067
SGA			
Yes	117 806	13 714	104 092
Preterm birth			
Yes	59 267	5887	53 380

SGA, small for gestational age.

perinatal mortality, SGA and preterm birth was 0.41%, 10.5% and 5.3%.

Spatial inequalities

Figures 2 and 3 illustrate the geographic variation in the prevalence of birth outcomes. These figures highlight regional differences, showcasing how birth outcomes vary across different areas.

Perinatal health outcomes

Perinatal mortality, SGA and preterm birth were higher (OR 1.13 (95% CI 1.024 to 1.241, p=0.014); OR 1.18 (95% CI 1.158 to 1.206, p<0.001); OR 1.09 (95% CI 1.056 to 1.119, p<0.001), respectively) in the designated high-risk areas compared with the rest of the Netherlands, after correction for multiple testing and covariates (table 2).

When comparing individual high-risk areas to the rest of the Netherlands, 4 of the 20 had significantly higher perinatal mortality (online supplemental table S2, figure 2). Regarding SGA, all high-risk areas had significantly higher rates compared with the rest of the Netherlands, after correction for multiple testing and covariates (online supplemental table S2, figure 2). Additionally, 6 of the 20 high-risk areas had higher rates of preterm birth compared with the rest of the country (online supplemental table S2, figure 2).

Compared with their respective municipalities, 3 of the 20 high-risk areas exhibited higher rates of perinatal mortality (online supplemental table S3). Moreover, 11 of the 20 areas exhibited higher rates of SGA (online supplemental table S3). Finally, 3 of the 20 areas showed higher rates of preterm birth (online supplemental table S3).

DISCUSSION

In this nationwide registry study, we examined geographical differences in perinatal health outcomes in a cohort over 1.1 million mother–child pairs in the Netherlands. We observed that the prevalence of perinatal mortality, SGA and preterm birth was significantly higher within and across designated high-risk areas—regions identified by the Dutch government based on safety and livability concerns—when compared with their respective municipalities and to the national average.

Our findings reveal important disparities that persist even in a high-income country with a well-developed healthcare system. This underscores the importance of considering the role of geographical inequalities in adverse perinatal outcomes. The neighbourhood in which one lives encompasses a wide array of environmental, social and infrastructural conditions that may

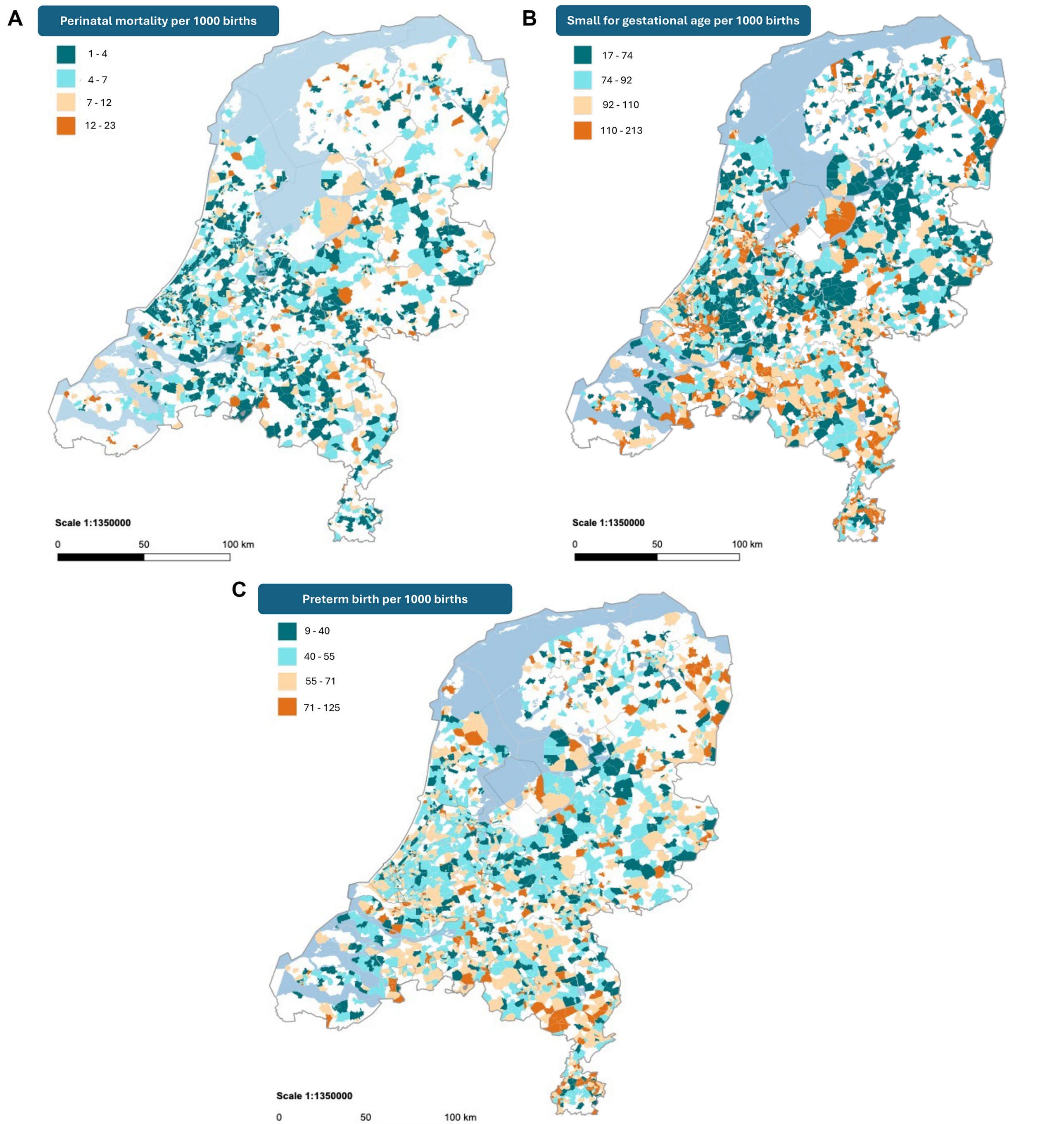

Figure 2 Prevalence map of perinatal mortality (A), preterm birth (B), and small for gestational age (C) across the Netherlands. The cut-offs shown are based on quartiles. Areas that had fewer than 1000 births were excluded (and therefore marked white).

influence health well before birth.[3–7 12] Studying such differences is, therefore, essential to fully understand the broader determinants of maternal and child health and to develop effective public health strategies. The current study marks the first step of a larger initiative aimed at investigating the actionable mechanisms that link geographic context—both in the preconception and pregnancy periods—to perinatal and early childhood health (specifically in the first 1000 days). Specifically, to support this mission, we have established a multidisciplinary collaboration between the Erasmus MC Department of Obstetrics and Gynecology, the Technical University Delft Faculty of Architecture, and the national government Ministries of Health, Welfare and Sports, Social Affairs and Employment, and Interior and Kingdom Relations, to ensure that scientific insights are translated into actionable and well-integrated policy interventions. Our initiative is embedded in the national Solid Start programme (https://www.kansrijkestart-ppp.nl), which is a transdisciplinary cross-sectoral partnership, aligned with the 'Health in All Policies' approach. This approach is unique and important as it goes beyond

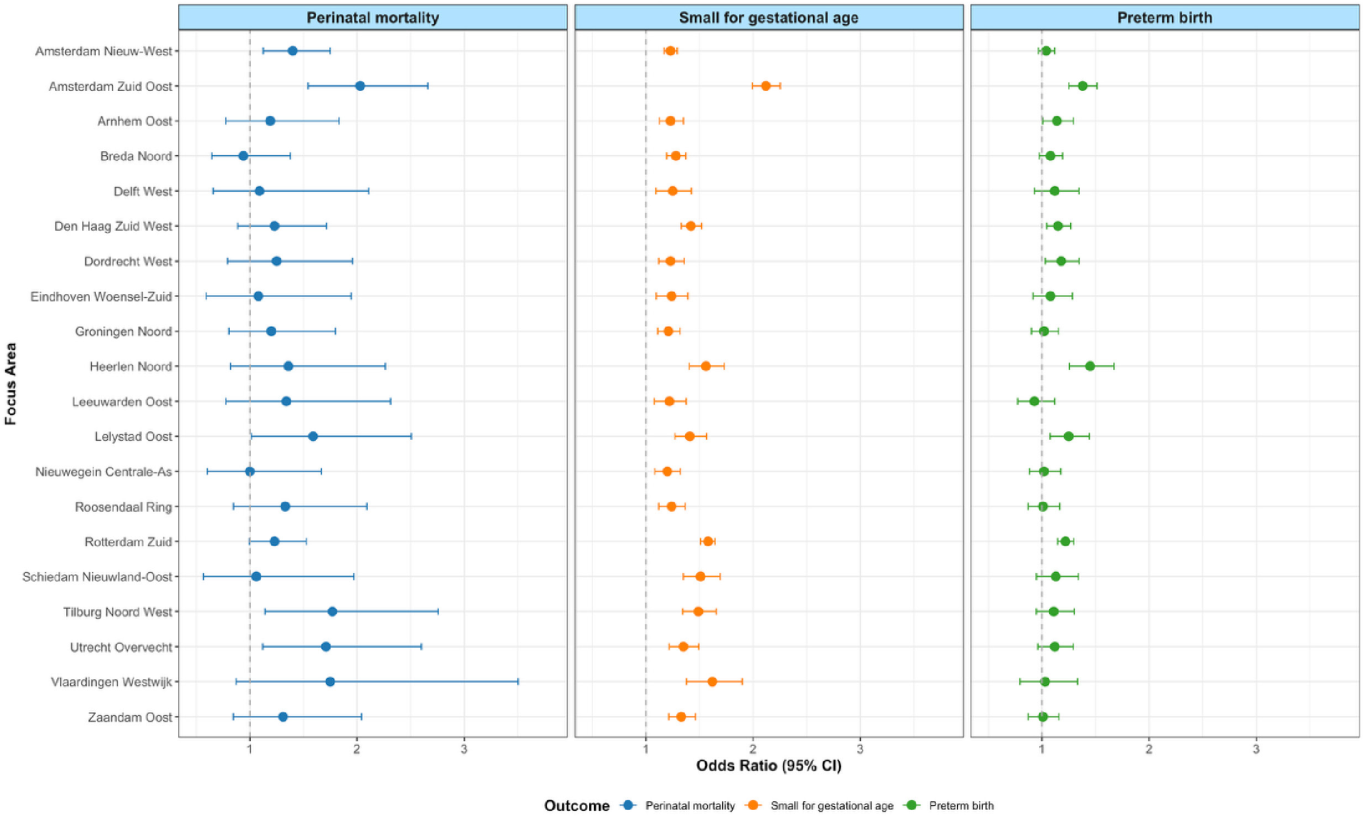

Figure 3 Birth outcomes in individual high-risk areas compared with the rest of the Netherlands.

the traditional health sector, systematically integrating health considerations into policymaking across multiple domains. By aligning scientific evidence with policy across sectors, we aim to create comprehensive strategies that can meaningfully reduce perinatal health inequalities at the population level.

A major strength of our approach is the use of a pragmatic design, in which we compare health outcomes across neighbourhoods with differing levels of livability and safety in a real-world setting. This provides a unique opportunity to study the urban environment as a determinant of health using robust, longitudinal and population-wide data. Moreover, we had access to over a million records providing sufficient power to detect significant associations. Nevertheless, several limitations should be considered when interpreting our findings. First, the observational nature of the study precludes causal inference; the associations observed between residence in high-risk areas and adverse perinatal outcomes may be influenced by unmeasured confounding, such as lifestyle-related factors, as our study had limited capacity to adjust for a broad range of confounders. However, it is worth noting that previous work from our group has shown that improvements in neighbourhood conditions were associated with significant improvement in perinatal health outcomes and vice versa.[15] Second, despite the high coverage of the Perined registry, some covariates contained missing data. Although the proportion of missingness was relatively low and unlikely to substantially bias the results, the use of complete case analysis may have introduced minor selection bias. Finally, our findings are specific to the Dutch context, including its healthcare system and the structure of the designated high-risk areas, which may limit generalisability to other settings. However, similar associations have been reported in studies conducted in other countries.[23–28] A final limitation is our subjective classification of the women's migration background during pregnancy.

Table 2 Birth outcomes in high-risk areas combined compared with the rest of the Netherlands

Outcome	OR	95% CI	P value
Perinatal mortality	1.13	1.024 to 1.241	0.014**
SGA	1.18	1.158 to 1.206	<0.001**
Preterm birth	1.09	1.056 to 1.119	<0.001**

Models were adjusted for maternal age, parity and migration background.
*p<0.05.
**p<0.017.
SGA, small for gestational age.

To better understand the potential mechanisms underlying the observed associations, a more comprehensive assessment of environmental influences is needed. The exposome concept emphasises the totality of environmental exposures—both outdoor and indoor—and social factors that an individual experiences throughout life.[3–8] Our initiative leverages this framework by considering both the outdoor neighbourhood environment and the indoor environment. Outdoor factors such as air pollution, noise, lack of green spaces, crime and elevated ambient temperatures have all been associated with poorer health outcomes and may plausibly contribute to adverse birth outcomes.[3–8] At the same time, the indoor exposome—shaped by building materials, ventilation, furniture, and resident behaviours—affects indoor air quality, temperature, humidity and noise levels, all of which may also influence maternal and fetal health. It will be our goal to identify modifiable environmental exposures using an exposome-based framework. According to the WHO, Europeans spend around 90% of their time indoors, emphasising the dire need to research the indoor exposome more in the context of perinatal health.

Finally, prior studies exploring the exposome in early life often focus on the pregnancy period, and the preconception period is often overlooked.[29] Our project enables the investigation of both short-term and long-term environmental exposures, offering insight not only into high-risk conditions but also into critical exposure windows, such as the preconception period, that may be particularly sensitive to environmental influences. This approach supports broader applications, including disentangling the effects of sustained exposure over time and evaluating potential impacts of residential relocation during pregnancy.

CONCLUSION

Our findings highlight persistent and significant geographical inequalities in perinatal health outcomes in the Netherlands. These disparities point to the urgent need for integrated, place-based strategies that address both social and environmental determinants of health from the earliest stages of life. Through continued interdisciplinary collaboration and the use of comprehensive data, we aim to uncover actionable insights that support equitable health outcomes for all children, regardless of where they are born.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval According to Dutch law (WMO), no formal ethical review was required. Perined provided approval (3156) for this research project. Contact person: e.a.p.steegers@erasmusmc.nl. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer-reviewed.

Data availability statement Data are available upon reasonable request. This study is based on registry data from the Dutch Perinatal Registry (Perined). Access to these birth records requires approval from Perined following the procedure on their website (www.perined.nl).

ORCID iDs
Anna J Suleri https://orcid.org/0000-0003-4860-7277
Frank van der Hoeven https://orcid.org/0000-0001-9308-0828
Eric A P Steegers https://orcid.org/0000-0002-4907-6466

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