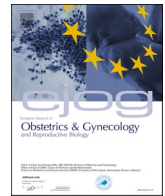




Contents lists available at ScienceDirect

European Journal of Obstetrics & Gynecology and Reproductive Biology

journal homepage: www.journals.elsevier.com/european-journal-of-obstetrics-and-gynecology-and-reproductive-biology

Full length article

Geographic variation in spontaneous preterm birth incidence at the province and municipal level in the Netherlands: A population registry based study

TE. Dijkhuis^{a,*}, MA. van Os^a, JV. Been^{b,c}, CJM. de Groot^d, ACJ. Ravelli^e, Preterm Birth Analyse Group¹^a Department of Obstetrics and Gynaecology, UMC Groningen, Groningen, the Netherlands^b Division of Neonatology, Department of Neonatal and Paediatric Intensive Care, Erasmus MC Sophia Children's Hospital, University Medical Centre Rotterdam, Rotterdam, the Netherlands^c Department of Obstetrics and Gynaecology, Erasmus MC Sophia Children's Hospital, University Medical Centre Rotterdam, Rotterdam, the Netherlands^d Amsterdam UMC, Department of Obstetrics and Gynaecology, Vrije Universiteit Amsterdam, the Netherlands^e Amsterdam, The Netherlands and Amsterdam Reproduction & Development, Amsterdam, the Netherlands

ARTICLE INFO

Keywords:

Preterm birth
Antenatal care
Ethnicity
Maternal health
Diversity
Social disadvantage

ABSTRACT

Preterm birth (PTB), defined as birth before 37 completed weeks of gestation, is a major public health concern with long-term health consequences. Risk factors for (spontaneous) PTB (sPTB) include medical, lifestyle, demographic, environmental, and obstetric factors. Low socioeconomic status (SES) and late initiation of antenatal care (ANC) are known contributors, but their municipal-level impact remains understudied. This study explores the distribution of sPTB across Dutch provinces and municipalities and assesses the role of SES and ANC in regional disparities to inform targeted, place-based interventions.

Data from the Netherlands Perinatal Registry (PERINED) on 952,262 singleton pregnancies (2016–2021) were analyzed. Incidence rates of PTB and sPTB were calculated per province and municipality. Logistic regression was used to calculate crude and adjusted sPTB odds ratios across 12 provinces and 364 municipalities. Adjustments were made for SES, late ANC, and risk factors including parity, maternal age, ethnicity, fetal sex and urbanisation level.

The incidence of sPTB was 3.6%, with substantial variation across provinces and municipalities (range 2.1–6.6%). Regional differences were partly influenced by SES, late initiation of ANC, and maternal and pregnancy-related characteristics, but persisted after adjustment. Additional adjustment for urbanisation attenuated these regional disparities.

There are marked geographic disparities in PTB and sPTB odds across the Netherlands, not fully explained by SES or late ANC. Further research into local environmental or contextual factors is needed to inform targeted strategies for improving perinatal health outcomes.

Introduction

Preterm birth (PTB), defined as delivery before 37 weeks of gestation, is a major public health issue due to its potential lifelong health consequences and significant impact on families and economic outcomes [1–3]. The causes of PTB are complex and multifactorial,

particularly in cases of spontaneous PTB (sPTB), where specific risk factors including a variety of medical, socioeconomic, demographic, environmental, and obstetric factors, are often difficult to identify [4,5]. Gaining insight into the distribution and underlying factors of sPTB is essential for guiding effective public health strategies.

Socioeconomic status (SES) is a known determinant of health, with

Abbreviations: PTB, preterm birth; sPTB, spontaneous preterm birth; mPTB, medically indicated preterm birth; SES, social economic status; ANC, antenatal care; SGA, small for gestational age; HDP, hypertensive disease of pregnancy; OR, odds ratio; CI, confidence interval.

* Corresponding author.

E-mail address: tessadijkhuis@gmail.com (TE. Dijkhuis).

¹ Preterm birth group analysis, See Appendix A for a full list of members and affiliations.

<https://doi.org/10.1016/j.ejogrb.2026.115036>

Received 3 August 2025; Received in revised form 30 January 2026; Accepted 22 February 2026

Available online 2 March 2026

0301-2115/© 2026 The Author(s). Published by Elsevier B.V. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

substantial evidence linking lower SES to an increased risk of PTB [6,7]. In addition to SES, late initiation of antenatal care (ANC), defined as first receiving care after 14 weeks of gestation, has been linked to an increased likelihood of sPTB, although studies on this subject are limited [8]. Despite the Netherlands' relatively egalitarian social system where antenatal care is free and easily accessible for citizens working or living in the Netherlands, notable geographic disparities in birth outcomes are evident across and within various regions Tromp et al., 2009; Bertens et al., [9,10]. Although recent data show some improvements, these regional disparities persist, making the Netherlands a valuable context for studying disparities in adverse birth outcomes Bertens et al., [10–12]. Research on national PTB trends indicates that while PTB rates have generally declined, these improvements have not extended to lower SES groups [12]. Recent national studies have also examined the geographical distribution of PTB, with a particular focus on urban areas where SES and ethnic disparities are often more pronounced Burgos Ochoa et al., 2021 Nov; Bertens et al., [6,10,13–17]. These studies underscore the influence of SES and neighbourhood deprivation on birth outcomes, providing important insights into birth outcomes within metropolitan regions.

Building on these findings, our study takes a next step by extending this analysis beyond urban areas to include rural areas by including all municipalities nationwide. By examining sPTB patterns across the whole country, we aim to determine if there are regional differences and if SES-differences provide a more comprehensive understanding of sPTB distribution differences nationwide. Additionally, as there is limited research on the impact of late entry into antenatal care (ANC) on sPTB, our study seeks to explore whether delayed entry of ANC is also a contributing factor to sPTB risk explaining the regional differences. The aim of the study is to analyze possible regional differences at provincial and municipal level in PTB and in specific sPTB and the role of SES, late initiation of ANC and other established risk factors in explaining these regional differences. This study also aims to identify regions where targeted preventive care is most needed to help reduce sPTB rates.

Methods

Study population and demographics

The Netherlands Perinatal Registry (PERINED) is a nationwide cohort and consists of population-based data on pregnancy, delivery and neonatal outcomes (<https://www.perined.nl>). The coverage of the PERINED registry is approximately 98% of all deliveries in The Netherlands.

For this study, we selected all registered pregnancies from January 1st 2016 to December 31st 2021. Multiple pregnancies and pregnancies with GA < 24 + 0 weeks and GA ≥ 43 + 0 weeks were excluded. In addition, we excluded records with missing postal code, neighbourhood deprivation index and municipalities with fewer than 10 sPTB cases, including “Rozendaal” and the small islands “Schiermonnikoog”, “Terschelling”, “Vlieland” and “Ameland”. Additional exclusion criteria for PTB were congenital abnormalities and antepartum fetal deaths.

Outcome measures

PTB was defined as birth before 37 + 0 completed weeks of gestation. sPTB included all preterm births after spontaneous onset of contractions, excluding iatrogenic deliveries (elective caesarean section or induction). Gestational age was based on first trimester crown rump length measurement or last menstrual period when the former was not available. Secondary outcome measurements were (s)PTB < 34 + 0, (s)PTB < 32 + 0 and (s)PTB < 28 + 0 weeks.

Determinant and covariables

All women’s residential four-digit postal codes were assigned to a

municipal area based on the municipal postal code list of 2016. Definitions of all determinants and covariates are listed in Table 1. These include SES (based on four-digit postal code), ANC timing, parity, maternal ethnicity, fetal sex, maternal age. Gestational diabetes, hypertensive disease of pregnancy (HDP) and small for gestational age (SGA) were included as descriptive variables. Crude odds ratios (ORs) were calculated for all variables.

Missing data

Less than 1% of data of the covariates were missing: maternal age (n = 2663), birthweight (n = 1355) and fetal sex (n = 65). These missing variables were imputed with a chained equation approach.

Statistical analysis

The unit of analysis in our study is the individual pregnancy/birth. Numbers and incidence of PTB and sPTB per 100 births were tabulated for each province and each municipality. We used logistic regression analyses to describe the crude PTB and sPTB ORs and 95% confidence intervals in each province and each municipality in The Netherlands. As the reference group, we selected the province or municipality with a risk of sPTB closest to the national average. As a sensitivity analysis, outcomes at the provincial level were stratified into three gestational age categories (<34, <32, and < 28 weeks) for both PTB and sPTB, with absolute numbers, percentages, and adjusted odds ratios reported.

Specifically for sPTB, we examined all municipalities with a significantly increased crude OR of sPTB in more detail. We performed a stepwise adjustment to explore the influence of various risk factors. Since SES and late initiation of ANC are central to our main research question, we conducted separate analyses for each of these factors in our first two models. In the third model, SES, late ANC, parity, maternal age,

Table 1
Definition and categorisation of the determinants and covariables.

Determinants	Definition and categorization
Social Economic Status (SES)	Four indicators SES was measured continues and dived in quintiles (Supplement table 2) 1. The proportion of residents with a low educational level 2. The average household income 3. The proportion of residents with a low income 4. Proportion of unemployed residents.
Late initiation of antenatal care (ANC)	Start ANC ≥14 weeks Yes/No
Parity	Nulliparous (P0) Multiparous (≥P1)
Maternal ethnicity	White (Caucasian) Mediterranean (Turkey/Morocco) African Creole (referred to as African) South Asian/Hindustan (referred to as South Asian) Other non-Western
Fetal sex	Male/female
Maternal age	<24 years 24–29 years 30–35 years ≥35 years
Hypertensive disease of pregnancy (HDP) (Gestational) diabetes	Pregnancy induced hypertension Pre-eclampsia/HELLP Gestational diabetes Diabetes mellitus type 1 and 2
Small for gestational age (SGAp10)	Birth weight centile for gestational age and sex less than 10 percentile
Urbanisation	Definition by Statistics Netherlands (CBS): Very strongly urbanized (≥2000 residents/km ²) Strongly urbanized (1000–1999 residents/km ²) Moderately urbanized (500–999 residents/km ²) Rural (250–499 residents/km ²) Very rural (<250 residents/km ²)

ethnicity, and fetal sex were included. In the fourth model urbanisation, a more environmental-level factor, was added to assess its area based contribution to the risk of sPTB. Bonferroni correction was applied in the adjusted logistic regression analysis. Here a more conservative significant p-value < 0.04 was used.

In addition, interaction between adjustment variables was assessed by including pairwise interaction terms in the logistic regression models. To provide insight into the significant interactions of urbanisation we calculated absolute risks of sPTB for relevant subgroups.

For the analysis of municipal and sPTB we compared sPTB with term births and medically indicated PTB (mPTB) combined, with a sensitivity analysis excluding mPTB.

The baseline characteristics are reported for the municipalities with an increased risk of sPTB, including maternal and pregnancy-related risk factors.

Data were analyzed using the SAS statistical software package, version 9.4 (SAS Institute Inc, NC, USA) and R version 4.3.2 with the MICE package.

Details of Ethics approval

Permission for use and analysis of data for the purpose of the study was obtained from the Netherlands Perinatal Registry (approval number 20.37). Anonymous registry data were used so no ethical approval was needed. Besides ethical approval, we contacted the regional caregivers to discuss our findings, both to converse about possible causes and avoid confrontation with unknown data after publication.

Results

Study population and baseline demographics.

In total, 969,383 singleton pregnancies between 24 + 0 and 42 + 6 weeks were observed in the national perinatal database between 2016 and 2021. Pregnancies with missing postal code were excluded, leaving $n = 958,666$ singleton pregnancies for final analysis. After excluding congenital anomalies and antepartum death, 952,262 pregnancies

remained. Data from 364 municipalities were included in the study, each comprising between 10 and 85 four-digit postal code areas. Fig. 1 shows the flowchart of our cohort.

The PTB incidence was 5.0% and the sPTB incidence was 3.6% ($n = 33,936$) with a range from 2.1% to 6.6%. To illustrate geographic patterns, the maps in Fig. 2 show the distribution of PTB and sPTB across the Netherlands, as well as the distribution of all births expressed as birth rates per km^2 across the municipalities (Fig. 2a–c).

The provinces Limburg and Brabant had a significantly increased risk in PTB and the province Limburg had a significantly increased risk of sPTB (Table 2). Subgroup analyses at the provincial level based on three gestational age categories (<34, <32, and < 28 weeks) for both PTB and sPTB indicated regional variation with additional differences identified in provinces Friesland and Gelderland (Supplement Table S4).

The municipalities with the most urbanised areas, Amsterdam ($n = 3072$) and Rotterdam ($n = 2530$), had the highest absolute numbers of PTB and sPTB (Supplement Table S1).

There were 17 municipalities with a significantly increased crude OR for sPTB compared to the mean risk (Table 3). Most of these municipalities were in the provinces Limburg and Brabant (Fig. 2b). Excluding mPTB did not change these results. Risk factors besides province or municipality that were associated with an increased risk for sPTB were: low SES, late ANC, nulliparity, maternal age < 24 years, male fetal sex and African, South-Asian and other non-Western ethnicity (Supplement Table S2). High SES and very rural urbanisation were protective for sPTB.

Women living in an area with low SES had an increased risk on sPTB with an OR of 1.11 95% CI (1.09–1.13). Therefore, we first adjusted the analysis for SES. In six out of the 17 municipalities the OR of sPTB that was no longer significantly elevated after adjusting for SES. However, in the remaining 11 municipalities, the elevated risk persisted even after adjusting for low SES (Table 3). Late initiation of ANC was associated with an increased OR for sPTB of 1.68 95% CI (1.64 – 1.73). In only two municipalities the sPTB OR was no longer significantly increased after adjusting for late initiation of ANC. After further adjusting for the additional risk factors for sPTB, including nulliparity, ethnicity,

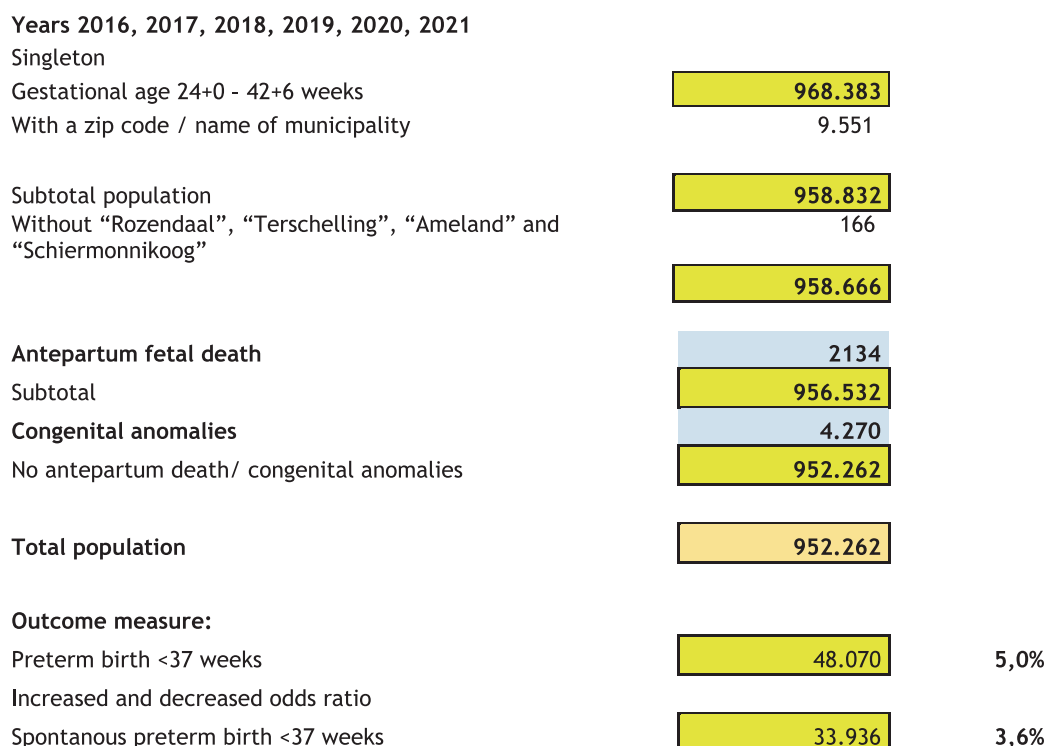
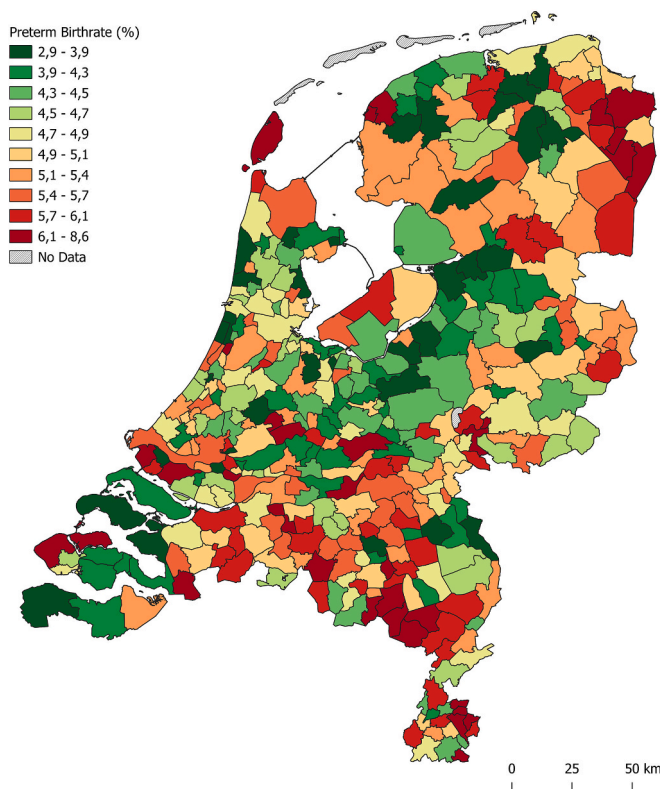


Fig. 1. Flowchart inclusions.

Geographic distribution of preterm birth across municipalities in the Netherlands



Geographic distribution of spontaneous preterm birth across municipalities in the Netherlands

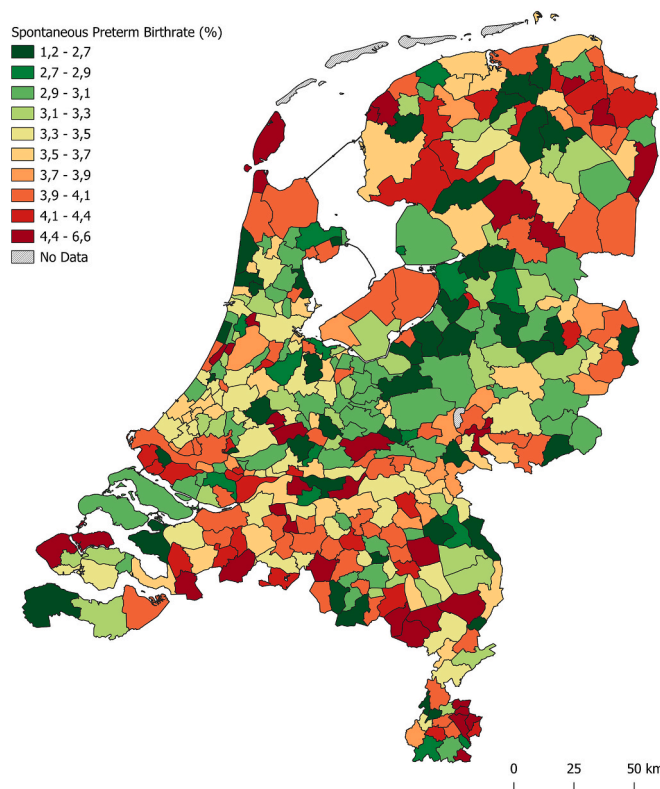


Fig. 2.

maternal age, and male fetal sex, 14 out of the 17 municipalities still showed an elevated OR for sPTB. After incorporating the level of urbanisation into the analysis, the association was no longer statistically significant in seven of the 17 municipalities.

The distribution of the risk factors for the 17 municipalities with increased risk for sPTB showed substantial heterogeneity in SES. Some municipalities had lower SES or late initiation of ANC. However not all municipalities with an increased sPTB risk were characterised in that way (Table 4). The majority of municipalities with a significantly increased risk of sPTB were characterized by a relatively low population density (rural area).

There was a significant interaction between urbanisation and the factors parity, ethnicity, and maternal age, as well as between SES and nulliparity and ethnicity (Supplementary Table S3). Table 5 presents the absolute risks of sPTB for the relevant combined subgroups stratified by urbanisation. Within rural areas, nulliparous women, women with a late initiation of ANC, and women of non-Western ethnicity tend to exhibit higher sPTB risks.

Discussion

We found that the incidence of PTB and sPTB varies significantly across provinces and municipalities in the Netherlands, uncovering notable regional disparities. Our analysis identified municipalities where the odds ratio for sPTB was significantly higher than the national average. These municipalities were predominantly located in the provinces of Brabant and Limburg. Although cities like Amsterdam and Rotterdam had the highest

absolute numbers of sPTB, they were not among the municipalities with the highest relative risk. Subgroup analyses at the provincial level, focussing on three gestational age categories (<34, <32, and < 28 weeks) for both PTB and sPTB, indicated regional variation, with additional differences identified in provinces Friesland and Gelderland (Supplement Table S4). Furthermore, in our study, the observed increase in sPTB appeared to be only partially influenced by low SES and late initiation of ANC.

Even after adjustment for additional established risk factors for sPTB, including parity, ethnicity, maternal age and fetal sex, the majority of municipalities continued to demonstrate an elevated risk. This suggests that these factors alone do not fully account for the observed geographical variation in the increased sPTB rates. After including urbanisation level in the model, the number of municipalities with a statistically significant increased risk of sPTB was reduced. This suggests that urbanisation, both toward an increased risk in the more urban settings and a more decreased risk in the more rural settings, may act as a mediating or confounding factor in the association between geographic location and sPTB risk at the municipal level. Notably, many of the municipalities with elevated risk were characterized by rural population sizes, indicating that risk factors for sPTB in combination with rural areas may have contributed more prominently to the observed differences. Our interaction analysis revealed that these rural areas also encompass groups typically considered at higher risk for sPTB, groups that are generally more prevalent in an urban population. One possible explanation is that preventive measures and monitoring efforts in large cities tend to prioritise these high-risk groups, which may render comparable women in rural settings less visible to healthcare providers.

Geographic distribution of birth rates across municipalities in the Netherlands (per km²)

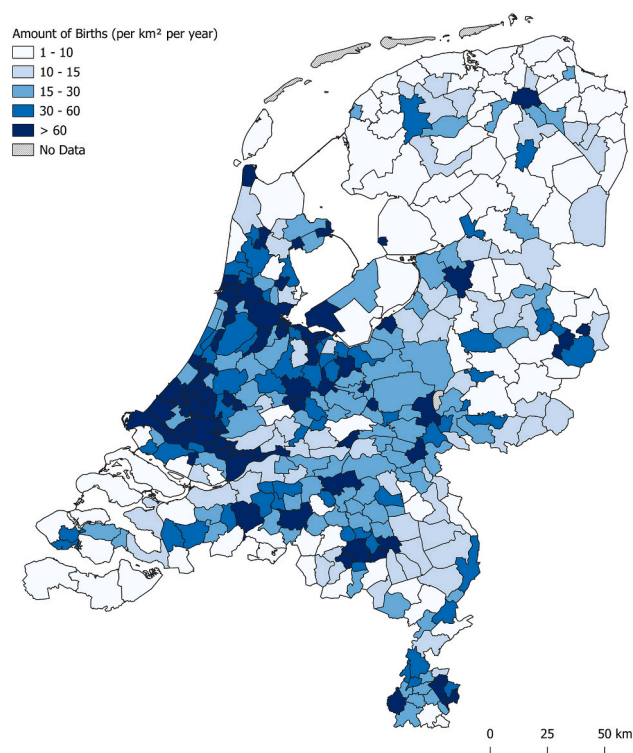


Fig. 2. (continued).

Table 2
Numbers and rated of PTB and sPTB by province in singletons in the years 2016–2021.

Provinces	Total births			Preterm birth (PTB)				spontaneous PTB (sPTB)		
	N	n	%	Odds ratio PTB	Adjusted Odds ratio #	n	%	Odds ratio sPTB	Adjusted Odds ratio #	
Groningen	28.692	1.511	5,27%	1.05 (0.98 – 1.13)	0.99 (0.92 – 1.06)	1.082	3,77%	1.03 (0.95 – 1.13)	1.001 (0.92 – 1.10)	
Friesland	32.514	1.638	5,04%	1.00 Reference	1.00 Reference	1.236	3,80%	1.04 (0.96 – 1.13)	1.06 (0.97 – 1.16)	
Drenthe	23.050	1.183	5,13%	1.02 (0.94 – 1.10)	1.02 (0.94 – 1.10)	849	3,68%	1.01 (0.92 – 1.11)	1.03 (0.93 – 1.13)	
Overijssel	63.200	3.065	4,85%	0.96 (0.90 – 1.02)	0.97 (0.91 – 1.03)	2.076	3,28%	0.89 (0.83 – 0.97)	0.92 (0.85 – 0.99)	
Gelderland	110.818	5.329	4,81%	0.95 (0.90 – 1.01)	0.98 (0.92 – 1.03)	3.769	3,40%	0.93 (0.86 – 0.99)	0.97 (0.90 – 1.04)	
Noord-Holland	166.193	7.986	4,81%	0.95 (0.90 – 1.01)	0.92 (0.87 – 0.97)	5.708	3,43%	0.94 (0.87 – 1.01)	0.93 (0.87 – 0.999)	
Flevoland	27.026	1.450	5,37%	1.07 (0.99 – 1.15)	1.04 (0.97 – 1.12)	989	3,66%	1.00 Reference	1.00 Reference	
Utrecht	81.663	3.780	4,63%	0.92 (0.86 – 0.97)	0.93 (0.88 – 0.99)	2.614	3,20%	0.87 (0.81 – 0.94)	0.91 (0.84 – 0.98)	
Zuid-Holland	219.580	11.393	5,19%	1.03 (0.98 – 1.09)	0.99 (0.94 – 1.05)	8.105	3,69%	1.01 (0.94 – 1.08)	1.01 (0.94 – 1.08)	
Noord-Brabant	132.765	7.156	5,39%	1.06 (1.01 – 1.12)	1.07 (1.01 – 1.13)	4.978	3,75%	1.03 (0.96 – 1.10)	1.03 (0.97 – 1.11)	
Zeeland	17.817	795	4,46%	0.88 (0.81 – 0.96)	0.86 (0.79 – 0.94)	599	3,36%	0.92 (0.83 – 1.02)	0.91 (0.82 – 1.01)	
Limburg	48.944	2.784	5,69%	1.14 (1.07 – 1.21)	1.08 (1.01 – 1.15)	1.931	3,95%	1.08 (1.00 – 1.17)	1.05 (0.97 – 1.13)	
Total	952.262	48.070	5,05%			33.936	3,56%			

adjusted for parity, age, late initiation of ANC, male fetal sex, ethnicity, SES.

Green = significant reduced (s)PTB.

Red = significant elevated (s)PTB.

Table 3

Municipalities with increased sPTB odds ratio's with crude and adjusted odds ratio's.

Province	Municipal	sPTB < 37 + 0 (3.6%)	Odds ratio 95% BI crude	Adjusted 1: SES quintilles	Adjusted 2: Late initiation of ANC	Adjustment: #3	Adjustment #4 = #3 and urbanisation
<i>Groningen</i>							
<i>Friesland</i>	Franekeadeel	5.2%	1.47 (1.06 – 2.05)	NS	1.54 (1.11 – 2.09)	1.49 (1.07 – 2.08)	NS
<i>Drenthe</i>	Hoogeveen	4.6%	1.30 (1.02 – 1.64)	NS	1.35 (1.07 – 1.70)	1.35 (1.06 – 1.70)	1.30 (1.10 – 1.54)
<i>Overijssel</i>							
<i>Noord Holland</i>	Texel	5.8%	1.65 (1.05 – 2.59)	1.57 (1.004 – 2.48)	NS	NS	NS
	Den Helder	4.6%	1.28 (1.001 – 1.62)	NS	NS	NS	NS
	Hillegom	4.9%	1.38 (1.02 – 1.88)	NS	1.46 (1.07 – 2.00)	1.43(1.05 – 1.95)	1.42 (1.08 – 1.82)
<i>Utrecht</i>							
<i>Flevoland</i>							
<i>Zuid-Holland</i>	Leidschendam- Voorburg'	3.6%	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)	1.00 (Ref)
<i>Brabant</i>	Dongen	5.0%	1.39 (1.04 – 1.87)	1.37 (1.02 – 1.84)	1.49 (1.11 – 1.99)	1.50 (1.11 – 2.01)	1.48 (1.15 – 1.88)
	Hilvarenbeek	5.6%	1.58 (1.08 – 2.30)	1.56 (1.07 – 2.29)	1.54 (1.06 – 2.52)	1.57 (1.07 – 2.30)	NS
	Woensdrecht	6.1%	1.72 (1.24 – 2.39)	1.69 (1.22 – 2.35)	1.77 (1.23 – 2.46)	1.71 (1.27 – 2.46)	1.75 (1.30 – 2.30)
	Cranendonck	5.0%	1.42 (1.02 – 1.97)	NS	1.49 (1.07 – 2.08)	1.54 (1.11 – 2.16)	1.51 (1.12 – 2.00)
	Geertruiden-berg	5.2%	1.45 (1.06 – 1.99)	1.42 (1.04 – 1.94)	1.52 (1.12 – 2.09)	1.48 (1.09 – 2.04)	1.47 (1.11 – 1.90)
<i>Zeeland</i>							
<i>Limburg</i>	Nederweert	5.2%	1.47 (1.04 – 2.08)	1.44 (1.01 – 2.05)	1.25 (1.01 – 1.55)	1.56 (1.10 – 2.21)	1.55 (1.12 – 2.09)
	Peel en Maas	4.7%	1.32 (1.01 – 1.71)	NS	1.33 (1.02 – 1.73)	NS	NS
	Landgraaf	5.6%	1.57 (1.19 – 2.07)	1.47 (1.12 – 1.95)	1.49 (1.13 – 1.97)	1.39 (1.05 – 1.84)	NS
	Brunssum	5.6%	1.58 (1.17 – 2.14)	1.49 (1.10 – 2.02)	1.48 (1.09 – 2.00)	1.38 (1.02 – 1.87)	NS
	Heerlen	5.1%	1.43 (1.15 – 1.78)	1.36 (1.09 – 1.70)	1.38 (1.10 – 1.72)	1.29 (1.03 – 1.62)	1.22 (1.05 – 1.42)
	Weert	4.8%	1.35 (1.05 – 1.72)	1.29 (1.003 – 1.65)	1.38 (1.08 – 1.77)	1.33 (1.03 – 1.71)	1.33 (1.09 – 1.59)
	Onderbanken	6.6%	1.89 (1.17 – 3.05)	1.89 (1.12 – 2.92)	1.80 (1.11 – 2.91)	1.76 (1.08 – 2.85)	1.73 (1.06 – 2.66)

Adjustment 1: Social Economic Status (SES).**Adjustment 2:** Late initiation of antenatal care (ANC).**Adjustment 3:** SES, Late initiation of ANC, parity, maternal age, SES, ethnicity, fetal sex.**Adjustment 4:** SES, Late initiation of ANC, parity, maternal age, SES, ethnicity, fetal sex and urbanisation.

NS = non significant p value >= 0.04.

Nonetheless, these findings do not fully account for the observed regional disparities, as a substantial proportion of the variation in sPTB risk remains unexplained. This suggests that additional, yet unidentified, contextual or environmental factors may be contributing to the observed disparities. These findings underscore the importance of investigating sPTB at the local level, as effective public health strategies may need to be tailored to the specific structural and social characteristics of individual municipalities.

Comparison with the literature

Our findings are consistent with previous studies that have identified regional disparities in sPTB in and across high human-development index countries. Zeitlin et al. found that, even across five high-income countries, two-thirds of all elevated risk for PTB remained unexplained despite known risk factors [18]. Our study adds to this perspective by demonstrating that even within a single country or healthcare system, substantial geographic disparities persist. The study by Murray et al. (2020) on preterm birth rates in Sweden also identified regional differences in preterm delivery rates within a single-country context and concluded that these variations could not be explained by

individual risk factors [19]. This aligns with our findings, where existing determinants only account for part of the observed variation. Conversely the U.S. county-level study on PTB rates (2007–2019) did find that counties with the greatest social disadvantage had the highest preterm and early PTB rates, with these disparities largely explained by place-based socioeconomic factors [20]. The discrepancy in findings may partly be explained by the inclusion of additional social determinants in their analysis, such as household composition and disability, minority status and language, and housing and transportation, which were not accounted for in our study. Similarly, previous research in the Netherlands has consistently shown that low SES, especially in urban neighbourhoods, is associated with higher sPTB risks Bertens et al., [10,13–16]. Our study suggests that, at the municipal level, regional differences in sPTB are only partially influenced by SES. This indicates that, although SES-related disparities are clearly present at the neighbourhood level, broader regional variations are likely influenced by additional factors beyond SES alone. However, the current method does not capture variation related to individual-level SES factors and does not account for differences within municipalities. This is particularly relevant in large municipalities such as Amsterdam and Rotterdam, where substantial variation at the individual level exists potentially obscuring

Table 4

The characteristics of the 17 municipals with significant increased crude risk on sPTB compared to the mean.

		sPTB	Very low and low SES	Late initiation of ANC	Nulliparae	Male fetal sex	White ethnicity	Age < 24 year	HDP	SGA p10	Very rural area
Total risk on sPTB < 37 + 0 weeks		3.6%	4.7%	5.3%	4.1%	4.0%	3.8%	5.2%	2.8%	3.8%	3.4%
%			40%	16.6%	45.0%	51.2%	22.3%	2.4%	4.7%	10.4%	11.2%
Province	Municipal										
Friesland	Franekeradeel	5.2%	97.3%	13.7%	43.5%	51.2%	23.6%	8.5%	3.5%	7.2%	33.9%
Drenthe	Hoogeveen	4.6%	71.0%	15.9%	40.8%	49.8%	9.9%	10.7%	4.7%	8.5%	25.9%
Noord Holland	Texel	5.8%	63.5%	90.4%	52.90%	54.7%	12.4%	9.6%	4.7%	8.9%	49.9%
	Den Helder	4.6%	59.7%	23.0%	41.1%	51.7%	17.8%	8.2%	9.1%	11.2%	0.8%
	Hillegom	4.9%	0.0%	12.7%	49.2%	48.5%	14.1%	3.8%	5.2%	9.4%	0.0%
Brabant	Dongen	5.0%	13.4%	11.5%	44.5%	51.2%	11.5%	4.2%	4.6%	11.1%	13.3%
	Hilvarenbeek	5.6%	0.0%	26.5%	45.0%	49.1%	8.6%	1.5%	3.1%	10.2%	44.8%
	Woensdrecht	6.1%	0.0%	17.6%	45.0%	51.8%	8.1%	7.5%	7.4%	12.5%	14.4%
	Cranendonck	5.0%	14.5%	13.8%	40.8%	52.3%	10.9%	5.9%	6.4%	8.4%	27.3%
	Geertruidenberg	5.2%	38.0%	14.5%	47.7%	52.6%	8.1%	6.4%	3.5%	10.0%	9.6%
Limburg	Nederweert	5.2%	0%	11.8%	44.7%	54.1%	5.7%	3.6%	8.0%	9.1%	38.8%
	Peel en Maas	4.7%	31%	20.3%	46.2%	52.2%	10.0%	3.1%	5.7%	10.6%	24.1%
	Landgraaf	5.6%	100%	31.4%	49.3%	49.0%	29.0%	7.5%	7.1%	13.4%	0.0%
	Brunssum	5.6%	100%	14.0%	48.1%	51.9%	32.7%	7.9%	6.0%	11.6%	0.0%
	Heerlen	5.1%	88.2%	29.9%	48.7%	51.3%	31.7%	12.0%	5.7%	13.5%	0.0%
	Weert	4.8%	65.8%	17.7%	45.4%	51.3%	15.3%	5.3%	7.6%	10.6%	0.0%
	Onderbanken	6.5%	54.5%	31.0%	44.5%	52.5%	23.8%	5.0%	4.6%	9.6%	45.5%

Table 5

Absolute risk of sPTB in combined subgroups of urbanisation with parity, ethnicity and maternal age and late initiation of ANC.

Urbanisation	Parity		Ethnicity				Maternal age				Late initiation of ANC		
	sPTB	Nulli parae	Multi parae	Caucasian	Mediterranean	African/Asian	Other Non Western	<24 years	24–29 years	30–34 years	=>35 year	<14 weeks	>= 14 weeks
Very urban	3,6%	4,3%	2,9%	3,5%	3,2%	4,4%	3,7%	5,1%	4,1%	3,6%	3,4%	3,2%	5,3%
Urban	3,6%	4,7%	2,7%	3,6%	3,2%	4,0%	3,8%	5,0%	4,7%	3,3%	3,4%	3,2%	5,4%
Mid	3,6%	4,9%	2,7%	3,6%	3,1%	3,9%	3,6%	4,9%	4,1%	3,4%	3,5%	3,2%	5,4%
Rural	3,5%	5,1%	2,4%	3,5%	2,2%	3,1%	4,0%	4,9%	4,0%	3,2%	3,2%	3,2%	5,3%
Very rural	3,4%	4,8%	2,3%	3,3%	2,3%	4,0%	4,0%	4,0%	3,9%	3,1%	3,2%	3,0%	5,0%
Total	3,6%	4,7%	2,7%	3,5%	3,1%	4,1%	3,76%	4,7%	3,8%	3,5%	3,3%	3,2%	5,3%

critical intra-urban disparities Agyemang et al., [15,21].

Strengths and limitations

A key strength of this study is that we were able to examine the nationwide distribution of sPTB at all municipalities in the Netherlands. This research builds on previous studies by shifting the focus beyond urban areas and municipalities already participating in the national Solid Start program ('Kansrijke Start') Burgos Ochoa et al., 2021 Nov; Bertens et al., [6,10,13–15,17,21]. 'Solid start' is a nationwide action programme in the Netherlands that aims to ensure that all children, regardless of their background, have the best possible start in life. It seeks to integrate medical and social care during the early stages of life by fostering collaboration between healthcare providers, social services, and local governments [22]. Furthermore, the use of comprehensive, nationwide data from the Netherlands Perinatal Registry (PERINED), covering over 950,000 singleton pregnancies over six years, significantly strengthens the study. The inclusion of multiple covariates further enhances the robustness of the findings.

However, several limitations of this study should be acknowledged. At the individual level, low SES has been consistently associated with a higher risk of sPTB, partly due to increased psychological stress among pregnant women with fewer socioeconomic resources [6,21,22]. Psychological distress is a well-established risk factor for sPTB. Additionally, stressors that are frequently, but not exclusively, associated with SES, such as work-related demands, environmental noise, and perceived

safety, may also contribute to unexplained regional variation in sPTB risk [21,23,24]. These factors were not the primary focus of the present study and not registered in the perinatal registry, but should be considered in future research. Additionally, the analysis could not account for other well-established contributors to sPTB that were either not included or under-registered in the perinatal registry, including smoking, low or high BMI, alcohol use, in vitro fertilization (IVF), and maternal medical history including previous PTB, all of which are critical factors influencing the risk of sPTB [23–26]. The absence of these and other variables may result in residual confounding in our analyses. While unhealthy behaviours are more commonly observed in populations with low SES, they are not limited to these groups [27,28].

The completeness of the Perinatal registry is 96%. All hospital births are included but not all midwifery practices are able to provide the data. This is for instance relevant for the island municipality of Texel. Texel does not contribute individual birth data to the national Perined registry yet, therefore only women delivering in mainland hospitals were included. This likely represents a higher-risk subset, as low-risk births usually occur on the island, which may introduce selection bias and contribute to the elevated sPTB rate observed for Texel in our analysis. Furthermore the estimates for municipalities with relatively small numbers of PTB or sPTB cases may be less stable.

Future research Directions

Our findings indicate that the observed regional variations in sPTB

are likely driven by additional, yet unidentified factors, highlighting the need for further research into the broader determinants of sPTB at the municipal level. To bridge these knowledge gaps, future studies should investigate a wide range of potential influences, including environmental exposures, the allocation of healthcare resources, cultural practices, and regional differences in healthcare access and delivery, as well as municipal and financial accessibility. In particular, attention should be paid to the role of urbanisation, especially mean and rural urbanisation. Although this factor is associated with sPTB, the current study does not allow for firm conclusions regarding the contribution and underlying mechanisms.

Future studies could incorporate phenotype-based frameworks, such as those proposed in contemporary taxonomies, to improve mechanistic insights and comparability across regions [29]. While our analysis was limited to available PERINED variables and could not classify (s)PTB by phenotype, emerging data offer opportunities to explore whether regional variation reflects underlying mechanisms or conception-related factors.

Finally, qualitative studies focusing on regions with higher sPTB rates across different gestational age groups could help clarify the local context, identify barriers, and provide valuable insights into unique, context-specific challenges, while also taking existing preventive programmes (e.g., “Solid Start” “first 1000 days”) into account for evaluation and potential refinement.

In conclusion this study highlights significant regional disparities in PTB and sPTB rates across the Netherlands, underscoring the need for multifaceted research into the unexplained sPTB variation at the municipal level. While low SES, late initiation of ANC and urbanisation appear to contribute to sPTB risk, they account for only part of the observed variation, suggesting that broader structural or regional factors may also play a role. Identifying and addressing these factors is essential for understanding and improving perinatal outcomes like sPTB and reducing regional inequalities.

Consent for publication

Not applicable.

Availability of data and materials

Data may be obtained from a third party, the Netherlands Perinatal Registry Foundation, and are not publicly available. However, access may be granted upon request following the procedure available at <http://www.Perined.nl/>. The other data set supporting the variables SES, urbanisation with four-digit postal codes is available via Central Bureau of Statistics (<https://www.cbs.nl>).

Authors' contributions

TD, MO, AR and CG designed the study. AR conducted the analyses. TD wrote the manuscript. TD, MO, AR, CG and JB contributed to the interpretation of the analyses and writing of the manuscript.

All authors approved the final manuscript. Members of the Preterm Birth Analysis group were consulted throughout the research process and were kept informed of the findings.

CRediT authorship contribution statement

TE. Dijkhuis: Writing – review & editing, Writing – original draft, Investigation, Conceptualization. **MA. van Os:** Writing – review & editing, Supervision, Conceptualization. **JV. Been:** Writing – review & editing. **CJM. de Groot:** Writing – review & editing, Supervision, Conceptualization. **ACJ. Ravelli:** Writing – review & editing, Methodology, Formal analysis, Data curation.

Ethics approval and consent to participate

The data used in this study were part of an anonymized database of routinely collected data and therefore approval of an Ethics Review Board was not necessary. Permission was given by Perined, the Dutch perinatal registry, to use records and analyse data.

Funding

None.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

We thank all Dutch perinatal healthcare professionals for data registration and the Netherlands Perinatal Registry Foundation (www.perinatereg.nl) for granting data access. We would also like to express our sincere gratitude to all the perinatal care networks (VSV's) involved in this study for their valuable contributions. We thank Geodienst, Research and Innovation support Groningen for help with the maps.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ejogrb.2026.115036>.

References

- [1] Althabe Fernando, Howson CPaul, Kinney Mary, Lawn Joy. Born too soon : the global action report on preterm birth. World Health Organization; 2012. 112 p.
- [2] Walther FJ, Den Ouden AL, Verloove-Vanhorick SP. Looking back in time: outcome of a national cohort of very preterm infants born in the Netherlands in 1983. *Early Hum Dev* 2000 Sep 1;59(3):175–91.
- [3] Burger RJ, Roseboom TJ, Ganzevoort W, Gordijn SJ, Pajkrt E, Abu-Hanna A, et al. Gestational age and socio-demographic factors associated with school performance at the age of 12 years, a population-based study. *Paediatr Perinat Epidemiol* 2023 Sep 1;37(7):643–51.
- [4] Schuster HJ, Peelen MJCS, Hajenius PJ, van Beukering MDM, van Eekelen R, Schonewille M, et al. Risk factors for spontaneous preterm birth among healthy nulliparous pregnant women in the Netherlands, a prospective cohort study. *Health Sci Rep* 2022. May 1;5(3).
- [5] Goldenberg RL, Culhane JF, Iams JD, Romero R. Epidemiology and causes of preterm birth. *Lancet* 2008;371:75–84.
- [6] Burgos Ochoa L, Bertens LC, Garcia-Gomez P, Van Ourti T, Steegers EA, Been JV. Association of neighbourhood socioeconomic trajectories with preterm birth and small-for-gestational-age in the Netherlands: a nationwide population-based study. *The Lancet Regional Health - Europe* 2021 Nov;1:10.
- [7] Daalderop LA, Lagendijk J, Steegers EAP, El Marroun H, Posthumus AG. Psychological distress during pregnancy and adverse maternal and perinatal health outcomes: the role of socioeconomic status. *International Journal of Gynecology and Obstetrics* 2023 Dec 1;163(3):920–30.
- [8] Beeckman K, Louckx F, Downe S, Putman K. The relationship between antenatal care and preterm birth: the importance of content of care. *Eur J Pub Health* 2013 Jun;23(3):366–71.
- [9] Tromp M, Eskes M, Reitsma JB, Erwich JJH, Brouwers HA, Rijninks-Van Driel GC, et al. Regional perinatal mortality differences in the Netherlands; Care is the question. *BMC Public Health* 2009;9.
- [10] Bertens LCM, Burgos Ochoa L, Van Ourti T, Steegers EAP, Been JV. Persisting inequalities in birth outcomes related to neighbourhood deprivation. *J Epidemiol Community Health* 1978;74(3):232–9.
- [11] Schaaf JM, Mol BWJ, Abu-Hanna A, Ravelli ACJ. Trends in preterm birth: Singleton and multiple pregnancies in the Netherlands, 2000–2007. *BJOG* 2011 Sep;118(10):1196–204.
- [12] Klumper J, Ravelli ACJ, Roos C, Abu-Hanna A, Oudijk MA. Trends in preterm birth in the Netherlands in 2011–2019: a population-based study among singletons and multiples. *Acta Obstet Gynecol Scand* 2024 Mar 1;103(3):449–58.
- [13] Vos AA, Denktas S, Borsboom GJJM, Bonsel GJ, Steegers EAP. Differences in perinatal morbidity and mortality on the neighbourhood level in dutch municipalities: a population based cohort study. *BMC Pregnancy Childbirth* 2015. Sep 2;15(1).

- [14] Ravelli ACJ, Steegers EAP, Rijninks-Van Driel GC, Abu-Hanna A, Eskes M, Verhoeff AP, et al. Perinatale sterfteverschillen in Amsterdam [Internet]. Ned Tijdschr Geneesk. 2011. Available from: www.cbs.nl.
- [15] Agyemang C, Vrijkotte TGM, Droomers M, Van Der Wal MF, Bonsel GJ, Stronks K. The effect of neighbourhood income and deprivation on pregnancy outcomes in Amsterdam, the Netherlands. *J Epidemiol Community Health* 2009;63(9):755–60.
- [16] van Winden T, Roos C, Hanna AA, Pajkrt E, Oudijk MA, Ravelli ACJ. Impact of ethnicity and neighborhood deprivation on preterm birth: how does urban living play a role? *European Journal of Obstetrics and Gynecology and Reproductive Biology* 2023 Mar;1(282):94–100.
- [17] Timmermans S, Bonsel GJ, Steegers-Theunissen RPM, MacKenbach JP, Steyerberg EW, Raat H, et al. Individual accumulation of heterogeneous risks explains perinatal inequalities within deprived neighbourhoods. *Eur J Epidemiol* 2011 Feb;26(2):165–80.
- [18] Ferrero DM, Larson J, Jacobsson B, Di RGC, Norman JE, Martin JN, et al. Cross-Country individual participant analysis of 4.1 million singleton births in 5 countries with very high human development index confirms known associations but provides no biologic explanation for 2/3 of all preterm births. *PLoS One* 2016. Sep 1;11(9).
- [19] Murray SR, Juodakis J, Bacelis J, Sand A, Norman JE, Sengpiel V, et al. Geographical differences in preterm delivery rates in Sweden: a population-based cohort study. *Acta Obstet Gynecol Scand* 2019 Jan 1;98(1):106–16.
- [20] Khan SS, Vaughan AS, Harrington K, Seegmiller L, Huang X, Pool LR, et al. US County-Level Variation in Preterm Birth rates, 2007-2019. *JAMA Netw Open* 2023 Dec 8;6(12):E2346864.
- [21] De Jonge HCC, Legendijk J, Saha U, Been JV, Burdorf A. Did an urban perinatal health programme in Rotterdam, the Netherlands, reduce adverse perinatal outcomes? Register-based retrospective cohort study. *BMJ Open* 2019. Oct 1;9(10).
- [22] Steegers EAP, Struijs JN, Uijtdewilligen AJM, Roseboom TJ. A good start for all children: Integrating early-life course medical and social care through Solid Start, the Netherlands' nationwide action programme. *Health Policy (New York)* 2025 Feb;1:152.
- [23] Torloni MR, Betrán AP, Daher S, Widmer M, Dolan SM, Menon R, et al. Maternal BMI and preterm birth: a systematic review of the literature with meta-analysis. *J Matern Fetal Neonatal Med* 2009 Nov;22(11):957–70.
- [24] Ratnasiri AWG, Gordon L, Dieckmann RA, Lee HC, Parry SS, Arief VN, et al. Smoking during Pregnancy and adverse Birth and Maternal Outcomes in California, 2007 to 2016. *Am J Perinatol* 2020 Nov 1;37(13):1364–76.
- [25] Dagklis T, Tsakiridis I, Mamopoulos A, Dardavessis T, Athanasiadis A. Modifiable risk factors for spontaneous preterm birth in nulliparous women: a prospective study. *J Perinat Med* 2020 Feb 1;48(2):96–101.
- [26] Smith GCS, Shah I, White IR, Pell JP, Crossley JA, Dobbie R. Maternal and biochemical predictors of spontaneous preterm birth among nulliparous women: a systematic analysis in relation to the degree of prematurity. *Int J Epidemiol* 2006 Jul 31;35(5):1169–77.
- [27] Baron R, Manniën J, te Velde SJ, Klomp T, Hutton EK, Brug J. Socio-demographic inequalities across a range of health status indicators and health behaviours among pregnant women in prenatal primary care: a cross-sectional study. *BMC Pregnancy Childbirth* 2015. Oct 13;15(1).
- [28] Lange AE, Mahlo-Nguyen J, Pierdant G, Allenberg H, Heckmann M, Ittermann T. Antenatal Care and Health Behavior of Pregnant Women—An Evaluation of the Survey of Neonates in Pomerania. *Children* 2023. Apr 1;10(4).
- [29] Villar J, Cavoretto PI, Barros FC, Romero R, Papageorgiou AT, Kennedy SH. Etiologically based Functional Taxonomy of the Preterm Birth Syndrome. *Clin Perinatol* 2024. <https://doi.org/10.1016/j.clp.2024.02.014>.