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Maternal social determinants of health: the hidden face of perinatal mortality in Mexico

Johnatan Torres-Torres[1,2*], Raigam Martinez-Portilla[1], Salvador Espino-y-Sosa[1], Irma Eloisa Monroy-Muñoz[1], Javier Perez-Duran[1], Juan Mario Solis-Paredes[1], Hector Borboa Olivares[1], Pablo Cerda-Flores[2], Lourdes Rojas-Zepeda[3] and Guadalupe Estrada-Gutierrez[4]

Abstract

Background Perinatal mortality, encompassing late stillbirths and neonatal mortalities, is a key indicator of maternal and neonatal health. Despite advances in health care, there have been alarming increased in perinatal mortality rates in Mexico. This study investigated the influence of social determinants on perinatal death in a Latin American middle-income country, aiming to inform equitable and effective health policies.

Methods A prospective cohort study was conducted with pregnant women from Mexico City. Data on the following clinical and social factors were collected: pregestational body mass index (pBMI), lupus, antiphospholipid syndrome (APS), preeclampsia, foetal growth restriction (FGR), social vulnerability, poverty, household overcrowding, and gender-based violence. Nested logistic regression models were developed to identify significant predictors of perinatal mortality, with the results reported as odds ratios (ORs) and 95% confidence intervals (CIs).

Results Among the 3,890 participants, there were 76 cases of perinatal mortality. Significant clinical predictors of perinatal mortality included higher pBMI (OR = 1.088, 95% CI 1.026–1.153), APS (OR = 10.049, 95% CI 1.843–54.803), and FGR (OR = 2.929, 95% CI 1.399–6.135), whereas high social vulnerability (OR = 5.332, 95% CI 2.485–11.443) and medium social vulnerability (OR = 3.084, 95% CI 1.528–6.222) emerged as significant social predictors of perinatal mortality. A comprehensive model incorporating both clinical and social determinants achieved an AUC of 0.921, with a detection rate of 67.1% and a false-positive rate of 10%, this indicating a significant improvement in perinatal mortality prediction. The inclusion of social determinants progressively enhanced predictive performance, underscoring their critical role in risk assessment.

Conclusions Clinical and social determinants significantly influence perinatal mortality. Addressing social inequalities and integrating social determinants into perinatal care could improve maternal and neonatal health outcomes. However, limitations such as reliance on self-reported data, ecological-level indicators for social vulnerability, and potential constraints on generalizability should be considered. These findings emphasize the need for targeted health policies to reduce social vulnerabilities and enhance health care access in middle-income countries.

Keywords Perinatal mortality, Social determinants of health, Risk assessment, Maternal health, Stillbirth, Neonatal mortality, Public health policy

*Correspondence:
Johnatan Torres-Torres
torresmmf@gmail.com

Full list of author information is available at the end of the article

Introduction

Perinatal mortality, which includes late stillbirths and neonatal mortalities, is a crucial indicator of maternal and neonatal health that reflects both health care quality and socioeconomic conditions [1]. The World Health Organization (WHO) estimates that approximately 2.3 million perinatal deaths occur annually worldwide [2]. In Mexico, perinatal mortality rates have increased by 4.65%, with estimated rates of 19.05, 19.10, and 19.98 per 1,000 live births in 2020, 2021, and 2022, respectively [3, 4].

Social determinants of health—conditions in which people are born, grow, live, work, and age—have strong impacts on health outcomes [5]. Factors such as family income, education, health care access, housing conditions, and social support significantly affect maternal and neonatal health [6, 7]. In middle-income countries, these determinants interact in complex ways, requiring comprehensive analysis to address disparities [8, 9].

Historically, medical and biological factors have been prioritized as primary contributors to perinatal mortality. Clinical risk factors include maternal age, preexisting medical conditions (e.g., hypertension, diabetes), pregnancy-related complications (e.g., preeclampsia, foetal growth restriction), and lifestyle factors (e.g., smoking, alcohol consumption) [10, 11]. However, emerging evidence has highlighted the significant role of social determinants in influencing perinatal outcomes [12, 13, 14, 15]. Maternal education, health care accessibility, prenatal care quality, housing conditions, and economic stability interact with clinical risks to shape perinatal health [8, 13, 16].

In middle-income countries such as Mexico, pronounced social inequalities exacerbate these risks. Low socioeconomic status limits access to high-quality health care, adequate nutrition, and timely medical intervention, thus compounding the effects of clinical risk factors [12, 17]. Addressing these disparities is essential for reducing perinatal mortality and improving maternal and neonatal health. Interventions in other countries targeting social determinants—such as policies to increase health care access, improve prenatal care, and alleviate poverty—have demonstrated effectiveness in mitigating these risks and narrowing health inequalities [18, 19, 20].

This study aimed to investigate the impact of social determinants on perinatal mortality in Mexico. By analysing the interplay between social determinants of health and perinatal outcomes, we seek to provide evidence to guide targeted interventions and policy development, ultimately contributing to reducing health disparities in Mexico and other Latin American middle-income countries facing similar socioeconomic challenges.

Methods

Study design and participants

This prospective cohort study examined the associations between social determinants of health and perinatal mortality. Pregnant women were recruited from the Romero Rubio Health Center and the Instituto Nacional de Perinatologia between October 2020 and April 2023. Participants were enrolled in the first trimester (11–13.6 weeks gestation) and followed up at subsequent visits during pregnancy (20, 24, 28, 32, and 36 weeks gestation) and the postpartum period. The inclusion criteria were as follows: females, over 18 years of age, and confirmed pregnancies. The exclusion criteria were as follows: chromosomal abnormalities, major foetal malformations, nonparticipation in follow-up, and consent withdrawal.

The participants were drawn from two different health care institutions to ensure cohort heterogeneity. The Romero Rubio Health Center, a primary-level facility, provides antenatal care for pregnant women at various risk levels, whereas the Instituto Nacional de Perinatologia, a tertiary centre, specializes in high-risk pregnancies. The protocol was approved by the Ethics and Research Committee of the Instituto Nacional de Perinatologia (Approval No. 2021-1-38), with adherence to the Declaration of Helsinki. Participation was entirely voluntary, and participants were informed of their right to withdraw at any time without repercussions. All the data collected were kept confidential and anonymized to protect the participants' privacy. Measures were taken to minimize any physical or psychological risks to the participants.

Data collection

Clinical and anthropometric data

The following maternal clinical and anthropometric data were extracted from medical records: maternal age, pregnancy type (spontaneous or assisted), parity (nulliparous or previous births), and medical history (preexisting diabetes, chronic hypertension, lupus, antiphospholipid syndrome (APS), polycystic ovary syndrome (PCOS), hypothyroidism, heart disease). Obstetric complications such as preeclampsia (PE) and foetal growth restriction (FGR) in previous and current pregnancies were also documented. Anthropometric markers included height, pregestational weight, and pregestational body mass index (pBMI).

Social determinants of health

Housing conditions

Housing conditions were assessed using a questionnaire that inquired about the number of people living in the house, the number of rooms available for living (excluding bathrooms and kitchens), and the general condition of the house. The WHO's overcrowding index guided the evaluation, defining overcrowding as having more than

three people per room [21]. To ensure accuracy and consistency, the participants provided detailed responses that were systematically analysed to determine the level of overcrowding and the general condition of the housing.

Social support

Social support was measured using the Medical Outcomes Study Social Support Survey (MOSSS) [22]. This survey included questions designed to capture the extent of emotional and practical support available from friends, family, and other social networks. The participants were asked to rate the availability of such support on a scale from 0 to 100. On the basis of their responses, the social support scores were categorized into three distinct levels: low (0–33), medium (34–66), and high (67–100).

Health insurance access

Participants' access to health insurance was assessed by asking whether they were affiliated with any social security scheme or private insurance. On the basis of their responses, the participants were categorized as either insured or uninsured. The insured category included individuals affiliated with the Mexican Social Security Institute (IMSS), which covers private-sector workers and their families; the Social Security Institution for Government Workers (ISSSTE), which serves public-sector employees; or those with private health insurance. The uninsured category comprised participants without any health coverage.

Mexico's health system combines public and private health care services. The IMSS and ISSSTE provide public health care for workers and their families in the formal economy, whereas the Ministry of Health offers services for uninsured individuals. This mixed model ensures the representation of participants from diverse health care access backgrounds in the study.

Gender-based violence

Experiences with gender-based violence were assessed using the Family Violence Questionnaire [23]. This comprehensive questionnaire included specific questions about experiences of physical, emotional, and sexual abuse. The participants were asked to reflect on their experiences over the past year and respond to targeted questions. The responses were scored on a scale from 0 to 30 to quantify the extent of violence experienced. The scores were categorized into three levels: none (0–9), moderate (10–19), or severe (20–30) gender-based violence [24].

Ensuring consistency and minimizing bias

To ensure consistency and reliability in questionnaire responses, data collectors, including obstetrics and maternal–foetal medicine residents and research interns, underwent standardized training sessions. Training covered the study's objectives, proper administration of questionnaires, and strategies to minimize biases. To reduce interviewer bias, data collectors were instructed to adhere strictly to the questionnaire script without providing guidance or suggestions. Clear and simple language was used in the questionnaires to ensure participant understanding, and participants were assured of confidentiality to encourage honest responses. Regular monitoring and supervision were conducted to maintain protocol adherence. Any inconsistencies in the responses were cross-checked against the original questionnaires and resolved to ensure data quality.

Social vulnerability index

The social vulnerability index, also called the social delay index, is a comprehensive metric used to rank the states of Mexico on the basis of their degree of social vulnerability at a specific time. For this study, each pregnant woman's social vulnerability index was determined on the basis of her postal code, reflecting the characteristics of the area where she lived rather than her individual circumstances. This ecological-level variable was included in the regression models to evaluate its association with perinatal mortality, alongside individual-level predictors. The index categorizes areas into five levels of social vulnerability: very low, low, medium, high, and very high. In this study, participants were assigned to three categories—low, medium, and high social vulnerability—on the basis of their postal codes. These categories were defined using thresholds established by the National Council for Evaluation of Social Development Policy (CONEVAL). None of the study participants resided in areas classified as very low or very high vulnerability, reflecting the socioeconomic distribution of the cohort. This index is formulated by summarizing four critical social deficiencies monitored by the National Council for Evaluation of Social Development Policy (CONEVAL). Educational lag measures the extent to which individuals in the population still need to complete basic educational levels appropriate for their age group. Access to health services reflects the proportion of the population that lacks access to essential health services, encompassing preventive, curative, and emergency care. Access to essential services in housing includes access to potable water, electricity, and sanitation facilities within the household. The quality of and space in housing assess the adequacy of living conditions in terms of the physical quality of housing structures and the availability of sufficient living space for household members [25].

Data on these social deficiencies are gathered through national surveys and statistical reports and then analysed to produce a comprehensive ranking. This ranking helps

identify areas with the highest levels of social vulnerability, thus guiding policy interventions and resource allocation to improve living conditions and reduce disparities.

Poverty and extreme poverty

The poverty index is based on the CONEVAL methodology. It considers current per capita income, average educational lag in a household, access to health care services, access to social security services, quality of and space in housing, access to quality and nutritious food, degree of social cohesion, and degree of accessibility to a paved road [26]. The poverty index in Mexico is divided into three categories: not poor, poor, and extremely poor. The 2022 poverty report and its methodology were published on 26 July 2023 (MCS-ENIGH 2022 report) [27].

Outcomes

The primary outcome was perinatal mortality, defined as late stillbirth (> 28 weeks gestation) or neonatal mortality (within the first month of life), in accordance with the definition provided by the WHO [28]. The secondary outcomes included stillborn and neonatal deaths separately.

Statistical analysis

The cohort was divided on the basis of the primary outcome: perinatal mortality versus non-perinatal mortality. Comparative analyses were conducted to identify differences in clinical and social variables between these groups. Continuous variables are expressed as medians with interquartile ranges (IQRs) and were analysed using the Mann–Whitney U test. Categorical variables are expressed as numbers and percentages and were analysed using the chi-square test or Fisher's exact test, as appropriate.

A nested logistic regression analysis was performed using a stepwise approach to assess the incremental value of the variables. Variables were added sequentially in hierarchical models, and their contributions to model fit and predictive performance were assessed. The first model included maternal health variables such as maternal age, type of pregnancy (spontaneous or assisted reproductive technology), smoking status, use of other drugs (cocaine/heroin), preexisting diabetes, chronic hypertension, lupus, APS, PCOS, hypothyroidism, previous PE, previous FGR, maternal history of PE, BMI, gestational age at delivery, current PE, and current FGR. The second model added basic socioeconomic indicators such as marital status, education level, and health insurance status to the variables in the first model. The third model included social support indicators such as high, medium, and low social support and experience of gender-based violence, in addition to the variables in the second model. The fourth model adds household overcrowding and poverty indicators to the variables in the third model. The fifth model incorporates vulnerability indices and all the variables from the fourth model.

Odds ratios (ORs) with 95% confidence intervals (CIs) were derived from the logistic regression analysis. Model performance was assessed using the likelihood-ratio chi-square test, with statistical significance set at $p < 0.05$. All analyses were performed using Stata Statistical Software, release 17, 2020 (Stata Corp., College Station, TX, USA).

Results

Cohort characteristics

Among the 3,890 participants, 76 (1.95%) experienced perinatal mortality (Table 1). Several clinical characteristics were significantly associated with perinatal mortality. The median pBMI was notably higher in the perinatal mortality group than in the control group (29.53 kg/m^2 vs. 26.81 kg/m^2; $p = 0.007$). Additionally, the prevalence of lupus (3.95% vs. 0.63%; $p = 0.001$) and the incidence of APS (3.95% vs. 0.42%; $p < 0.001$) were significantly greater in the perinatal mortality group. The median gestational age at delivery was significantly lower in the perinatal mortality group than in the control group (35.0 weeks vs. 38.0 weeks, $p = 0.001$). Newborn weight was also significantly lower in the perinatal mortality group than in the control group (2370 g vs. 2749.5 g; $p = 0.001$). PE was significantly more prevalent in the perinatal mortality group (7.89% vs. 3.57%; $p = 0.046$), as was FGR (15.79% vs. 5.17%; $p < 0.001$).

Significant differences were also observed in various social determinants. Social security coverage was lower in the perinatal mortality group than in the control group (69.74% vs. 80.15%; $p = 0.025$). Household overcrowding was significantly more prevalent among those who experienced perinatal mortality (10.53% vs. 4.20%; $p = 0.007$). The level of experience with gender-based violence was significantly greater in the perinatal mortality group (9.21% vs. 4.06%; $p = 0.026$). Additionally, social support levels varied, with significantly lower levels of high social support (21.05% vs. 31.93%) and significantly higher levels of low social support (27.63% vs. 17.12%) in the perinatal mortality group ($p = 0.023$). With respect to socioeconomic status, the rates of poverty (26.32% vs. 16.91%; $p = 0.031$) and extreme poverty (9.21% vs. 4.43%; $p = 0.047$) were significantly higher in the perinatal mortality group. The vulnerability index also highlighted significant disparities, with a higher prevalence of high vulnerability in the perinatal mortality group (35.53% vs. 16.12%; $p < 0.001$) and a lower prevalence of low vulnerability (17.11% vs. 46.04%).

Table 1 Characteristics of the study population ($n = 3980$)

	Control group $n = 3814$	Perinatal mortality $n = 76$	p value
Maternal age (years)	31 (24–38)	29 (23-36.5)	0.131
Nulliparity	1287 (33.74%)	28 (36.84%)	0.572
Spontaneous pregnancy	3740 (98.06%)	75 (98.68%)	0.695
Induction of ovulation	31 (0.81%)	1 (1.32%)	0.430
IVF	41 (1.07%)	0	0.364
Smoker	272 (7.13%)	7 (9.21%)	0.487
Alcohol intake	71 (1.86%)	1 (1.32%)	0.230
Other drugs	66 (1.73%)	4 (5.26%)	0.022
Preexisting diabetes	198 (5.19%)	2 (2.63%)	0.317
Chronic hypertension	111 (2.91%)	4 (5.26%)	0.230
Lupus	24 (0.63%)	3 (3.95%)	0.001
APS	16 (0.42%)	3 (3.95%)	< 0.001
PCOS	83 (2.18%)	1 (1.32%)	0.609
Hypothyroidism	379 (9.94%)	6 (7.89%)	0.555
Congenital heart disease	12 (0.31%)	0	0.624
PE in a previous pregnancy	265 (6.95%)	6 (7.89%)	0.748
FGR in a previous pregnancy	233 (6.11%)	5 (6.58%)	0.866
Mother of the patient had PE	186 (4.88%)	5 (6.58%)	0.496
pBMI	26.81 (22.67–30.84)	29.53 (25.63–31.26)	0.007
Social security, n (%)	3057 (80.15%)	53 (69.74%)	0.025
Household overcrowding	160 (4.20%)	8 (10.53%)	0.007
Gender-based violence	155 (4.06%)	7 (9.21%)	0.026
Social support			
High	1218 (31.93%)	16 (21.05%)	0.023
Medium	1943 (50.94%)	39 (51.32%)	
Low	653 (17.12%)	21 (27.63%)	
Vulnerability indices			
High, n (%)	615 (16.12%)	27 (35.53%)	< 0.001
Medium, n (%)	1443 (37.83%)	36 (47.37%)	
Low, n (%)	1756 (46.04%)	13 (17.11%)	
Family income	8000 (3500–12000)	5000 (4250–8000)	0.136
Poor, n (%)	645 (16.91%)	20 (26.32%)	0.031
Extreme poverty, n (%)	169 (4.43%)	7 (9.21%)	0.047
Gestational age at delivery	38 (36–40)	35 (34–36)	0.001
Newborn weight	2749.5 (2123–3581)	2370 (1813–2565)	0.001
Current PE	136 (3.57%)	6 (7.89%)	0.046
Current FGR	197 (5.17%)	12 (15.79%)	< 0.001

PE: preeclampsia; IVF: in vitro fertilization; APS: Antiphospholipid syndrome; PCOS: Polycystic ovary syndrome; pBMI: pregestational body mass index; FGR: foetal growth restriction

Incremental impact of clinical and social determinants on predicting perinatal mortality

Predictive models for perinatal mortality were developed incrementally, and additional sets of variables were incorporated to assess their significance (Table 2). Model 1, which included only maternal health variables, served as the baseline. Model 2, which incorporated basic socioeconomic indicators, showed modest improvement over Model 1 (LR chi2 = 4.30, $p = 0.2310$). Model 3, which added social support indicators, further improved upon Model 2 (LR chi2 = 6.59, $p = 0.0861$). Model 4, which incorporates household overcrowding and poverty indicators, demonstrated additional enhancement (LR chi2 = 8.04, $p = 0.0451$). Finally, Model 5, which included vulnerability indices, showed the most significant improvement (LR chi2 = 21.48, $p < 0.001$). Nested logistic regression analysis revealed that several clinical and social factors were significantly associated with perinatal mortality. Among the clinical determinants, FGR was significantly associated with increased risk (OR = 2.93, $p = 0.004$), as were preeclampsia (OR = 3.56, $p = 0.001$), APS (OR = 10.05, $p = 0.008$), and pregestational BMI (OR = 1.09, $p = 0.004$). Gestational age at delivery had a protective effect against perinatal mortality (OR = 0.51, $p < 0.001$).

With respect to social determinants, high social support significantly reduced the risk of perinatal mortality (OR = 0.51, $p = 0.083$), whereas household overcrowding significantly increased the risk (OR = 2.07, $p = 0.095$). The vulnerability index was particularly significant, with high vulnerability (OR = 5.33, $p < 0.001$) and medium vulnerability (OR = 3.08, $p = 0.002$) being strong predictors of increased perinatal mortality risk (Fig. 1).

Impact of including social determinants on predictive accuracy for perinatal mortality

The predictive performance of the nested models for perinatal mortality improved significantly with the inclusion of social determinants (Fig. 2). Model 1, which included only clinical variables, had an AUC of 0.878, a DR of 0.566 and a an FPR of 10%. Adding basic social determinants in Model 2 increased the AUC to 0.887 and the DR to 0.579. Social support in Model 3 further improved the AUC to 0.898 and the DR to 0.618. Model 4, which included overcrowding and poverty, achieved an AUC of 0.903 and a DR of 0.658. Finally, Model 5, which added vulnerability indices, reached the highest AUC of 0.921 and a DR of 0.671, thus highlighting the critical role of social factors in predicting perinatal mortality.

Predictive performance of nested models for secondary outcomes

The predictive accuracy for secondary outcomes improved significantly as social determinants were included in the model. For stillbirth, the AUC increased progressively from 0.910 (95% CI: 0.858–0.964) in Model 1 to 0.965 (95% CI: 0.943–0.987) in Model 5. The DR at a 10% FPR also improved from 0.652 (95% CI: 0.478–0.870) in Model 1 to 0.783 (95% CI: 0.609–0.957) in Model 5. For neonatal mortality, the AUC increased from 0.860 (95% CI: 0.824–0.896) in Model 1 to 0.896 (95% CI:

Table 2 Nested logistic regression models for perinatal mortality

Variable	Model 1 Maternal Health Model		Model 2 + Basic Socioeconomic Indicators		Model 3 + Social Support		Model 4 + Overcrowding and Poverty		Model 5 + Vulnerability Indices	
	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Maternal Age	0.986 (0.956–1.018)	0.391	0.986 (0.955–1.017)	0.365	0.985 (0.954–1.016)	0.336	0.983 (0.952–1.015)	0.303	0.982 (0.950–1.014)	0.269
Spontaneous pregnancy	1.119 (0.145–8.645)	0.914	1.068 (0.138–8.260)	0.950	1.047 (0.133–8.215)	0.965	0.971 (0.122–7.688)	0.978	0.685 (0.088–5.318)	0.717
Smoker	1.403 (0.589–3.339)	0.444	1.453 (0.611–3.457)	0.398	1.478 (0.621–3.520)	0.377	1.440 (0.603–3.438)	0.411	1.660 (0.701–3.932)	0.249
Other Drugs (Cocaine/Heroin)	4.301 (1.277–14.480)	**0.019**	4.308 (1.287–14.423)	**0.018**	4.064 (1.188–13.906)	**0.025**	3.891 (1.126–13.448)	**0.032**	3.109 (0.842–11.878)	0.089
Preexisting Diabetes	0.300 (0.058–1.556)	0.152	0.299 (0.055–1.617)	0.161	0.276 (0.048–1.575)	0.148	0.277 (0.049–1.553)	0.145	0.304 (0.053–1.764)	0.184
Chronic Hypertension	2.582 (0.878–7.593)	0.085	2.615 (0.885–7.732)	0.082	2.426 (0.814–7.229)	0.112	2.263 (0.754–6.787)	0.145	2.185 (0.708–6.742)	0.174
Lupus	3.161 (0.691–14.457)	0.138	3.174 (0.701–14.370)	0.134	2.889 (0.630-13.246)	0.172	3.355 (0.725–15.516)	0.121	3.052 (0.652–14.292)	0.157
APS	14.548 (3.323–63.696)	**<0.001**	11.800 (2.498–55.741)	**0.002**	11.058 (2.226–54.924)	**0.003**	9.532 (1.859–48.883)	**0.007**	10.049 (1.843–54.803)	**0.008**
PCOS	0.871 (0.113–6.682)	0.894	0.926 (0.120–7.145)	0.941	0.949 (0.122–7.370)	0.960	1.002 (0.129–7.812)	0.998	0.928 (0.114–7.543)	0.944
Hypothyroidism	0.675 (0.267–1.707)	0.406	0.687 (0.269–1.752)	0.432	0.696 (0.272–1.787)	0.452	0.729 (0.282–1.883)	0.514	0.812 (0.310–2.124)	0.671
Previous PE	0.963 (0.371-2.500)	0.938	1.080 (0.414–2.819)	0.875	1.110 (0.423–2.913)	0.832	1.178 (0.447–3.098)	0.740	1.165 (0.427–3.182)	0.766
Previous RCF	1.454 (0.543–3.888)	0.456	1.415 (0.525–3.810)	0.493	1.386 (0.511–3.754)	0.521	1.421 (0.525–3.844)	0.489	1.226 (0.441–3.404)	0.696
Mother with PE	1.033 (0.366–2.915)	0.951	1.086 (0.384–3.070)	0.876	1.097 (0.386–3.120)	0.861	1.189 (0.416–3.398)	0.746	1.096 (0.374–3.216)	0.867
pBMI	1.094 (1.034–1.156)	**0.002**	1.093 (1.033–1.156)	**0.002**	1.090 (1.030–1.153)	**0.003**	1.090 (1.029–1.155)	**0.003**	1.088 (1.026–1.153)	**0.004**
Gestational Age at delivery	0.513 (0.451–0.583)	**<0.001**	0.512 (0.450–0.583)	**<0.001**	0.512 (0.449–0.583)	**<0.001**	0.508 (0.445–0.579)	**<0.001**	0.510 (0.447–0.583)	**<0.001**
Current PE	2.120 (0.833–5.399)	0.115	2.214 (0.866–5.660)	0.097	2.135 (0.826–5.519)	0.117	1.989 (0.767–5.161)	0.157	1.858 (0.694–4.974)	0.218
Current RCF	2.917 (1.441–5.904)	**0.003**	2.852 (1.403–5.796)	**0.004**	2.891 (1.421–5.881)	**0.003**	2.978 (1.463–6.064)	**0.003**	2.929 (1.399–6.135)	**0.004**
Nulliparity	0.993 (0.588–1.676)	0.978	1.010 (0.597–1.710)	0.969	0.996 (0.586–1.690)	0.987	0.971 (0.569–1.654)	0.913	0.945 (0.550–1.625)	0.839
Marital Status			1.002 (0.719–1.397)	0.991	1.002 (0.718–1.399)	0.990	1.010 (0.722–1.412)	0.913	1.058 (0.749–1.494)	0.749

Table 2 (continued)

Variable	Model 1 Maternal Health Model		Model 2 + Basic Socioeconomic Indicators		Model 3 + Social Support		Model 4 + Overcrowding and Poverty		Model 5 + Vulnerability Indices	
	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value	OR (95% CI)	*p* value
Education			0.929 (0.719–1.199)	0.570	0.909 (0.703–1.176)	0.468	0.896 (0.691–1.163)	0.410	0.873 (0.671–1.135)	0.310
Health Insurance			0.554 (0.319–0.962)	**0.036**	0.566 (0.324–0.989)	**0.046**	0.591 (0.336–1.040)	0.068	0.586 (0.329–1.041)	0.068
High Social Support					0.428 (0.204-0.900)	**0.025**	0.433 (0.205–0.916)	**0.029**	0.511 (0.239–1.093)	0.083
Medium Social Support					0.701 (0.383–1.280)	0.247	0.685 (0.373–1.258)	0.223	0.748 (0.403–1.390)	0.359
Gender Violence					1.937 (0.767–4.894)	0.162	1.708 (0.669–4.358)	0.263	1.483 (0.575–3.826)	0.415
Overcrowding							2.073 (0.882–4.871)	0.095	1.741 (0.729–4.159)	0.212
Poverty							1.553 (0.764–3.155)	0.224	1.139 (0.549–2.364)	0.726
Extreme Poverty							1.522 (0.529–4.377)	0.435	1.817 (0.622–5.311)	0.275
High Vulnerability									5.332 (2.485–11.443)	**<0.001**
Medium Vulnerability									3.084 (1.528–6.222)	**0.002**
LR Chi-squared	199.09	<0.001	4.30	0.231	6.59	0.861	8.04	0.045	21.48	**<0.001**

The table presents the results of five nested logistic regression models, each constructed through the stepwise addition of variable sets to evaluate their contribution to model fit and predictive performance. The odds ratios (OR) with 95% confidence intervals (CI) and *p* values are displayed for each variable across the different models. The models were developed to identify factors associated with perinatal mortality, considering clinical, socioeconomic, social support, gender violence, overcrowding, poverty, and vulnerability variables. Significant variables ($p < 0.05$) are highlighted in the table. APS: Antiphospholipid syndrome; PCOS: Polycystic ovary syndrome; PE: Preeclampsia; FGR: Foetal Growth Restriction

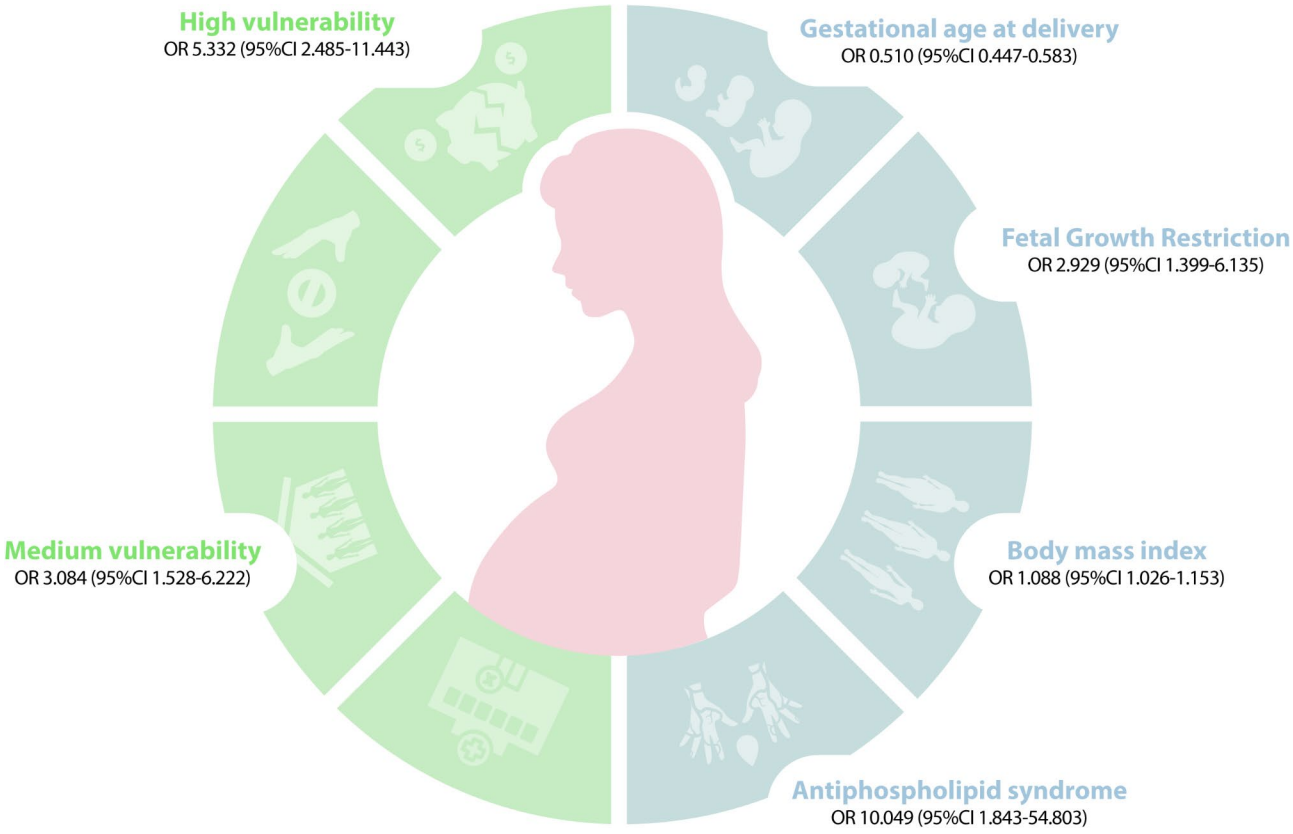

Fig. 1 Significant clinical and social factors associated with perinatal mortality risk. The clinical factors included antiphospholipid syndrome (OR = 10.049, 95% CI 1.843–54.803, $p = 0.008$), body mass index (OR = 1.088, 95% CI 1.026–1.153, $p = 0.004$), foetal growth restriction (OR = 2.929, 95% CI 1.399–6.135, $p = 0.004$), and gestational age at delivery (OR = 0.510, 95% CI 0.447–0.583, $p < 0.001$). The social factors included high vulnerability (OR = 5.332, 95% CI 2.485–11.443, $p < 0.001$) and medium vulnerability (OR = 3.084, 95% CI 1.528–6.222, $p = 0.002$), which are strong predictors of increased perinatal mortality risk

0.868–0.924) in Model 5. The DR improved from 0.472 (95% CI: 0.340–0.623) in Model 1 to 0.604 (95% CI: 0.472–0.736) in Model 5 (Table 3).

Discussion

Main findings

This study provides a comprehensive analysis of the combined influence of social determinants and clinical risk factors on perinatal mortality in a middle-income country, offering new insights into the interaction between these factors and perinatal mortality. By integrating a broad range of social determinants—including housing conditions, social support, access to health insurance, gender-based violence, social vulnerability, and poverty—our research quantified their collective impact on perinatal outcomes and demonstrated how they enhanced predictive accuracy. This study fills a critical gap in existing research by providing a unified framework that explicitly incorporates both biomedical and social factors, which are often studied in isolation. Unlike previous studies that focused primarily on either clinical or social aspects, our findings highlight how their interplay significantly improves the identification of high-risk pregnancies. By applying this comprehensive approach, we generated actionable evidence to guide equitable health policies and design targeted interventions aimed at reducing perinatal mortality, particularly in middle-income settings such as Mexico.

Comparison with existing literature

Our findings build on existing evidence linking clinical and social determinants to perinatal mortality while addressing a critical gap in understanding their interaction, particularly in middle-income countries with pronounced social inequalities. Research has consistently identified clinical factors such as PE, FGR, and maternal pBMI as major contributors to perinatal outcomes [29, 30, 31, 32]. PE disrupts placental function, increasing the risk of poor foetal growth and preterm birth, whereas FGR is associated with neonatal mortality due to complications such as hypoxia [30]. Additionally, maternal pBMI, whether underweight or overweight, has been strongly linked to adverse outcomes, including gestational diabetes and preterm birth [31, 32]. Autoimmune

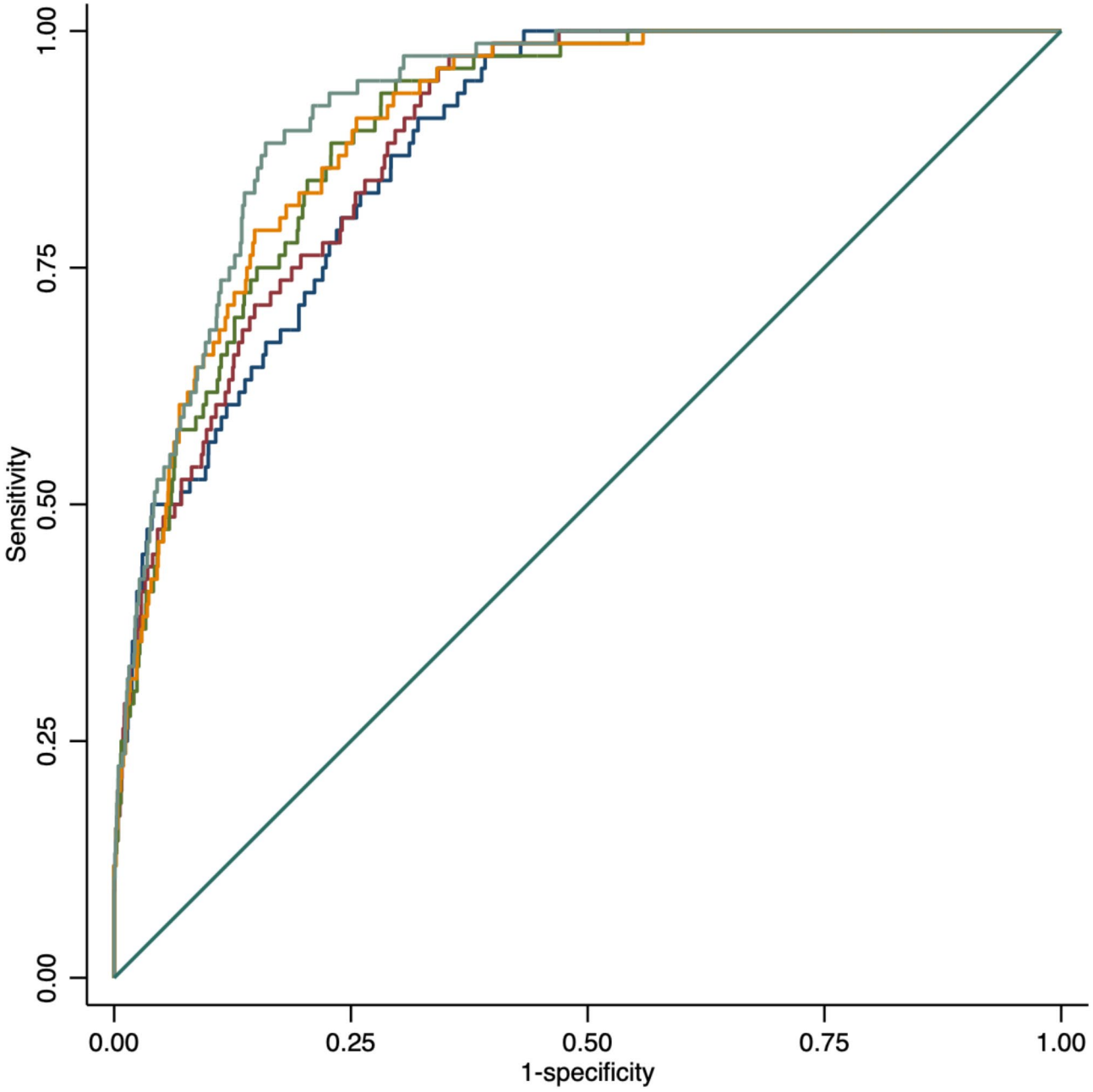

Fig. 2 Receiver operating characteristic (ROC) curves showing the incremental improvement in perinatal mortality prediction when social determinants are added to clinical models. Model 1 (blue line) includes only clinical variables and has an area under the curve (AUC) of 0.878 (95% CI: 0.849–0.909), with a detection rate (DR) of 0.566 (95% CI: 0.428–0.658) at a 10% false-positive rate (FPR). Model 2 (red line) adds basic social determinants, increasing the AUC to 0.887 (95% CI: 0.859–0.915) and the DR to 0.579 (95% CI: 0.461–0.711). Model 3 (green line) incorporates social support, further improving the AUC to 0.898 (95% CI: 0.878–0.924) and the DR to 0.618 (95% CI: 0.500-0.724). Model 4 (orange line) includes overcrowding and poverty, achieving an AUC of 0.903 (95% CI: 0.877–0.929) and a DR of 0.658 (95% CI: 0.539–0.776). Model 5 (gray line) adds vulnerability indices, reaching the highest AUC of 0.921 (95% CI: 0.899–0.942) and a DR of 0.671 (95% CI: 0.579–0.789)

disorders such as lupus and APS further exacerbate these risks, increasing the likelihood of thrombotic events, recurrent pregnancy loss, and severe complications such as preeclampsia [33, 34].

Consistent with previous studies, our findings reinforce the critical role of social determinants in shaping perinatal health. For example, Bauserman et al. demonstrated that low socioeconomic status significantly increases the risk of preterm birth and low birth weight [35]. Similarly, in a systematic review, Eggleston et al. emphasized the profound impact of social and economic factors on maternal and neonatal health, particularly in

Table 3 Predictive performance of nested models for secondary outcomes

	AUC (95% CI)	DR at 10% FPR (95% CI)
Model 1 (Maternal Health Model)		
Stillbirth	0.910 (0.858–0.964)	0.652 (0.478–0.870)
Neonatal mortality	0.860 (0.824–0.896)	0.472 (0.340–0.623)
Model 2 (+ Basic Socioeconomic Indicators)		
Stillbirth	0.924 (0.876–0.972)	0.652 (0.435–0.826)
Neonatal mortality	0.866 (0.833-0.900)	0.528 (0.387–0.679)
Model 3 (+ Social Support)		
Stillbirth	0.935 (0.897–0.974)	0.696 (0.478–0.870)
Neonatal mortality	0.876 (0.842–0.910)	0.566 (0.434–0.708)
Model 4 (+ Overcrowding and Poverty)		
Stillbirth	0.942 (0.904–0.981)	0.739 (0.565–0.913)
Neonatal mortality	0.881 (0.848–0.914)	0.604 (0.472–0.736)
Model 5 (+ Vulnerability Indices)		
Stillbirth	0.965 (0.943–0.987)	0.783 (0.609–0.957)
Neonatal mortality	0.896 (0.868–0.924)	0.604 (0.472–0.736)

FPR: False-positive rate; CI: confidence interval; AUC: Area under the curve; DR: Detection rate

low- and middle-income countries [36]. Our study aligns with these findings, as high social vulnerability emerged as a strong predictor of perinatal mortality, thus reaffirming the link between socioeconomic disparities and adverse birth outcomes [9, 37]. Poverty and extreme poverty remain key barriers to health care access, adequate nutrition, and timely medical interventions, thus exacerbating the adverse effects of clinical risk factors [37, 38].

Other social determinants, such as gender-based violence and inadequate social support, also play crucial roles in perinatal health. Gender-based violence has been linked to complications such as preterm birth, low birth weight, and foetal injury [33], highlighting the urgent need for screening and intervention strategies to protect vulnerable pregnant women. Additionally, low social support contributes to anxiety, depression, and inadequate prenatal care, all of which negatively impact perinatal outcomes [9]. Our findings underscore the importance of fostering supportive environments for expectant mothers to mitigate these risks.

By integrating social determinants into predictive models for perinatal mortality, we significantly increased their accuracy. Our nested models demonstrate the added value of incorporating variables such as high and medium social vulnerability, highlighting the potential of advanced analytics in guiding health care providers to identify high-risk pregnancies and implement tailored interventions. These findings highlight the necessity for a holistic approach that extends beyond clinical risk factors alone.

Policymakers and health care practitioners must consider the broader social context in which expectant mothers live, recognizing the profound influence of social determinants on health outcomes. Targeted interventions to reduce social inequalities and improve access to health care, adequate housing, and social support networks are essential. By incorporating these considerations into public health strategies, we can develop comprehensive and equitable solutions to reduce the burden of perinatal mortality and improve maternal and neonatal health in resource-limited settings.

Clinical and policy implications

Targeted policies that address social determinants can play a crucial role in reducing perinatal mortality. On the basis of our findings, interventions should prioritize housing improvements through government-supported subsidies and low-interest housing loans for pregnant women and families at high risk for perinatal mortality. Programs similar to successful international initiatives that provide temporary housing assistance for pregnant women living in overcrowded or unsafe environments could be adapted to the Mexican context, ensuring that vulnerable populations have access to stable and safe housing during pregnancy [39, 40, 41].

Additionally, expanding health care access through mobile health clinics in underserved communities and strengthening IMSS-BIENESTAR, Mexico's primary public health care program for uninsured populations, could significantly reduce disparities by providing universal prenatal care coverage. The incorporation of Mexico's 'First 1,000 Days' strategy—which focuses on maternal nutrition, early childhood development, and comprehensive perinatal care—could further improve maternal and neonatal health outcomes. Home visit programs led by community health workers could also enhance early detection of at-risk pregnancies, thus ensuring timely medical intervention and linkage to essential services. These initiatives should be integrated with local health services to proactively identify at-risk families during prenatal care.

Strengthening social support networks is also essential. Community-based initiatives, such as prenatal support groups and outreach programs, can provide resources and emotional support for pregnant women, particularly those experiencing gender-based violence or social isolation. Establishing screening protocols within health care settings for gender-based violence, along with referral systems to support services, could mitigate its adverse effects on perinatal outcomes.

Reducing social vulnerability is another critical goal. Policies should address economic disparities through targeted educational and employment programs, ensuring equitable access to health care and essential resources. For example, subsidies or incentives for health care access in low-income communities could directly address the barriers identified in our study.

To effectively reduce perinatal mortality, an integrated approach is needed. Policymakers should foster collaboration between the health and social sectors to deliver comprehensive care that accounts for both clinical and social determinants. Evidence-based policies informed by studies such as ours can guide the development of tailored interventions that are relevant and effective in specific local contexts.

Sustained funding for programs addressing poverty, housing, and social support is crucial, as these investments not only improve maternal and neonatal health but also foster long-term community benefits by reducing health inequities and promoting economic development.

Strengths and limitations

A major strength of this study is its prospective cohort design, which allows for the calculation of incidence rates that reflect real-world population dynamics. This study acknowledges the persistent influence of social determinants, even within a controlled research setting, enhancing its relevance and applicability. By addressing both intrinsic (clinical) and extrinsic (social) factors, our research offers a more comprehensive understanding of perinatal mortality, thus informing more effective public health policies.

The use of nested models is another key strength, as it systematically evaluates the incremental value of clinical and social determinants in predicting perinatal mortality. Our findings emphasize the necessity of integrating social vulnerability indices and other social factors into risk assessments.

Despite its strengths, this study has several limitations. The use of self-reported data for social determinants such as housing conditions, social support, and gender-based violence may introduce recall bias and social desirability bias. Future research should incorporate objective measures (e.g., official socioeconomic records and third-party assessments) to increase data reliability.

Another limitation is the context-specific findings. This study is based on Mexico´s health care system and social structure, which may limit its generalizability to other middle-income countries. Comparative studies across diverse settings would be valuable for validating these associations.

Additionally, this study measures social vulnerability at an ecological level, using community characteristics derived from postal codes, which may not fully capture individual-level variability. Future research should explore ways to integrate both individual- and area-level data for a more precise risk assessment.

Another limitation is the underestimation of perinatal mortality because cases occurring outside medical facilities were not captured, potentially leading to an underestimation of the true burden of perinatal mortality.

Finally, although robust cross-validation methods were used, further validation in diverse populations is needed to confirm their broader applicability.

Conclusion

This study underscores the significant impact of both clinical and social determinants on perinatal mortality. Addressing social inequalities through targeted public health policies is crucial for reducing preventable perinatal deaths. Future research should focus on validating predictive models across diverse health care systems and refining risk assessment by integrating individual-level social determinants and objective socioeconomic measures.

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Author contributions

JTT: Conceptualization, Methodology, Formal analysis, Writing– original draft and editing. PCF and LRZ: Methodology and Investigation. RMP, SEyS, and GEG: Writing– the original draft and editing. IEMM, JPD, JMSP, and HBO: Methodology and editing.

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Data availability

The datasets used and/or analysed during the current study are available upon reasonable request. Access to the data may be granted to those who provide a justified request for research purposes. To request access, please contact torresmmf@gmail.com.

Declarations

Ethics approval and consent to participate

The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of Instituto Nacional de Perinatologia "Isidro Espinosa de los Reyes" (protocol code 2021-1-38). Informed consent was obtained from all the subjects involved in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]Department of Reproductive and Perinatal Health Research, Instituto Nacional de Perinatología "Isidro Espinosa de los Reyes", Mexico City, México
[2]Obstetric and Gynecology Department, Hospital General de México "Dr. Eduardo Liceaga", Mexico City, México
[3]Maternal-Fetal Department, Instituto Materno Infantil del Estado de Mexico, Toluca, México
[4]Department of Immunobiochemistry, Instituto Nacional de Perinatología "Isidro Espinosa de los Reyes", Mexico City, México

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References

1. Bailey PE, Andualem W, Brun M, et al. Institutional maternal and perinatal deaths: a review of 40 low and middle income countries. BMC Pregnancy Childbirth. 2017;17(1):295.
2. WHO. Newborn mortality. 2024. https://www.who.int/news-room/fact-sheets/detail/newborn-mortality
3. INEGI. Estadísticas De Defunciones Registradas (EDR). 2022. Comunicado de prensa número 644/23. 2023.
4. Mundial GB. Tasa de mortalidad, neonatal (por cada 1.000 nacidos vivos) - Latin America & Caribbean. 2024. https://datos.bancomundial.org/indicador/SH.DYN.NMRT?locations=ZJ
5. Marmot M, Bell R. Fair society, healthy lives. Public Health. 2012;126(Suppl 1):S4–10.
6. Idnay B, Fang Y, Stanley E, et al. Promoting equity in clinical research: the role of social determinants of health. J Biomed Inf. 2024;156:104663.
7. Imran A, Rawal MD, Botre N, Patil A. Improving and promoting social determinants of health at a system level. Jt Comm J Qual Patient Saf. 2022;48(8):376–84.
8. Keepanasseril A, Pal K, Maurya DK, Kar SS, Bakshi R, D'Souza R. Impact of social determinants of health on progression from potentially life-threatening complications to near miss events and death during pregnancy and post partum in a middle-income setting: an observational study. BMJ Open. 2024;14(5):e081996.
9. Irangani L, Prasanna IR, Gunarathne SP, et al. Social determinants of health pave the path to maternal deaths in rural Sri Lanka: reflections from social autopsies. Reprod Health. 2022;19(1):221.
10. Lawn JE, Ohuma EO, Bradley E, et al. Small babies, big risks: global estimates of prevalence and mortality for vulnerable newborns to accelerate change and improve counting. Lancet. 2023;401(10389):1707–19.
11. Hug L, You D, Blencowe H, et al. Global, regional, and National estimates and trends in stillbirths from 2000 to 2019: a systematic assessment. Lancet. 2021;398(10302):772–85.
12. Mahato PK, Waithaka E, van Teijlingen E, Pant PR, Biswas A. Social autopsy: a potential health-promotion tool for preventing maternal mortality in low-income countries. WHO South East Asia J Public Health. 2018;7(1):24–8.
13. Li Y, Zhang Y, Fang S, et al. Analysis of inequality in maternal and child health outcomes and mortality from 2000 to 2013 in China. Int J Equity Health. 2017;16(1):66.
14. Gao Y, Zhou H, Singh NS, et al. Progress and challenges in maternal health in Western China: a countdown to 2015 National case study. Lancet Glob Health. 2017;5(5):e523–36.
15. Souza JP, Day LT, Rezende-Gomes AC, et al. A global analysis of the determinants of maternal health and transitions in maternal mortality. Lancet Glob Health. 2024;12(2):e306–16.
16. Knight L, Yamin A. Without a mother: caregivers and community members' views about the impacts of maternal mortality on families in KwaZulu-Natal, South Africa. Reprod Health. 2015;12(Suppl 1):S5.
17. McMaughan DJ, Oloruntoba O, Smith ML. Socioeconomic status and access to healthcare: interrelated drivers for healthy aging. Front Public Health. 2020;8:231.
18. Reyes AM, Akanyirige PW, Wishart D, et al. Interventions addressing social needs in perinatal care: A systematic review. Health Equity. 2021;5(1):100–18.
19. Harriett LE, Eary RL, Prickett SA, et al. Adaptation of screening tools for social determinants of health in pregnancy: A pilot project. Matern Child Health J. 2023;27(9):1472–80.
20. Hofmeyr GJ, Black RE, Rogozińska E, et al. Evidence-based antenatal interventions to reduce the incidence of small vulnerable newborns and their associated poor outcomes. Lancet. 2023;401(10389):1733–44.
21. Organization WH. WHO Housing and health guidelines. 2018. https://www.who.int/publications/i/item/9789241550376
22. Dao-Tran TH, Lam LT, Balasooriya NN, Comans T. The medical outcome study social support survey (MOS-SSS): A psychometric systematic review. J Adv Nurs. 2023;79(12):4521–41.
23. Garcia-Moreno C, Jansen HA, Ellsberg M, Heise L, Watts CH. Prevalence of intimate partner violence: findings from the WHO multi-country study on women's health and domestic violence. Lancet. 2006;368(9543):1260–9.
24. Screening for family. And intimate partner violence: recommendation statement. Ann Intern Med. 2004;140(5):382–6.
25. Social CNdEdlPdD. Índice de Rezago Social. https://www.coneval.org.mx/Medicion/IRS/Paginas/Anexo-Metodologico-del-Indice-de-Rezago-Social.aspx
26. Social CNdEdlPdD. Medición de la pobreza. 2022. https://www.coneval.org.mx/Medicion/Paginas/PobrezaInicio.aspx
27. Social CNdEdlPdD. Pobreza en México.
28. WHO. Maternal and perinatal death and surveillance and response. 2021. https://www.who.int/publications/i/item/9789240036666
29. von Dadelszen P, Magee LA. Preventing deaths due to the hypertensive disorders of pregnancy. Best Pract Res Clin Obstet Gynaecol. 2016;36:83–102.
30. Conti-Ramsden FI, Nathan HL, De Greeff A, et al. Pregnancy-Related acute kidney injury in preeclampsia: risk factors and renal outcomes. Hypertension. 2019;74(5):1144–51.
31. Torres-Torres J, Martinez-Portilla RJ, Espino YSS, et al. Comorbidity, poverty and social vulnerability as risk factors for mortality in pregnant women with confirmed SARS-CoV-2 infection: analysis of 13 062 positive pregnancies including 176 maternal deaths in Mexico. Ultrasound Obstet Gynecol. 2022;59(1):76–82.
32. Seo N, Lee YM, Kim YJ, et al. Obesity is associated with higher risk of adverse maternal and neonatal outcomes than supervised gestational diabetes. J Korean Med Sci. 2023;38(33):e268.
33. Thumm EB, Rees R, Nacht A, Heyborne K, Kahn B. The association between maternal mortality, adverse childhood experiences, and social determinant of health: where is the evidence?? Matern Child Health J. 2022;26(11):2169–78.
34. D'Ippolito S, Barbaro G, Paciullo C, Tersigni C, Scambia G, Di Simone N. Antiphospholipid syndrome in pregnancy: new and old pathogenetic mechanisms. Int J Mol Sci 2023; 24(4).
35. Bauserman M, Nowak K, Nolen TL, et al. The relationship between birth intervals and adverse maternal and neonatal outcomes in six low and lower-middle income countries. Reprod Health. 2020;17(Suppl 2):157.
36. Eggleston AJ, Richards A, Farrington E, et al. Randomised trials in maternal and perinatal health in low and middle-income countries from 2010 to 2019: a systematic scoping review. BMJ Open. 2022;12(7):e059473.
37. Alves FJO, Ramos D, Paixão ES, et al. Association of conditional cash transfers with maternal mortality using the 100 million Brazilian cohort. JAMA Netw Open. 2023;6(2):e230070.
38. Patel AB, Bann CM, Kolhe CS, et al. The global network socioeconomic status index as a predictor of stillbirths, perinatal mortality, and neonatal mortality in rural communities in low and lower middle income country sites of the global network for women's and children's health research. PLoS ONE. 2022;17(8):e0272712.
39. Cutts DB, Meyers AF, Black MM, et al. US housing insecurity and the health of very young children. Am J Public Health. 2011;101(8):1508–14.
40. Sandel M, Sheward R, Ettinger de Cuba S et al. Unstable housing and caregiver and child health in renter families. Pediatrics 2018; 141(2).
41. Reece J. More than shelter: housing for urban maternal and infant health. Int J Environ Res Public Health 2021; 18(7).

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