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Research paper

Socioeconomic inequalities in low birth weight risk before and during the COVID-19 pandemic in Argentina: A cross-sectional study



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ABSTRACT

Background: The coronavirus disease 2019 (COVID-19) pandemic may have exacerbated existing socioeconomic inequalities in health. In Argentina, public hospitals serve the poorest uninsured segment of the population, while private hospitals serve patients with health insurance. This study aimed to assess whether socioeconomic inequalities in low birth weight (LBW) risk changed during the first wave of the COVID-19 pandemic.

Methods: This multicenter cross-sectional study included 15929 infants. A difference-in-difference (DID) analysis of socioeconomic inequalities between public and private hospitals in LBW risk in a pandemic cohort (March 20 to July 19, 2020) was compared with a prepandemic cohort (March 20 to July 19, 2019) by using medical records obtained from ten hospitals. Infants were categorized by weight as LBW < 2500 g, very low birth weight (VLBW) < 1500 g and extremely low birth weight (ELBW) < 1000 g. Log binomial regression was performed to estimate risk differences with an interaction term representing the DID estimator. Covariate-adjusted models included potential perinatal confounders.

Findings: Of the 8437 infants in the prepandemic cohort, 4887 (57.9%) were born in public hospitals. The pandemic cohort comprised 7492 infants, 4402 (58.7%) of whom were born in public hospitals. The DID estimators indicated no differences between public versus private hospitals for LBW risk (-1.8% [95% CI $-3.6, 0.0$]) and for ELBW risk (-0.1% [95% CI $-0.6, 0.3$]). Significant differences were found between public versus private hospitals in the DID estimators (-1.2% [95% CI, $-2.1, -0.3$]) for VLBW risk. The results were comparable in covariate-adjusted models.

Interpretation: In this study, we found evidence of decreased disparities between public and private hospitals in VLBW risk. Our findings suggest that measures that prioritize social spending to protect the most vulnerable pregnant women during the pandemic contributed to better birth outcomes.

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Research in context

Evidence before this study

Low birth weight is an important measure of health because it is a leading risk factor for infant mortality as well as a marker for subsequent child morbidity among infants who survive; it is also an important predictor of health and socioeconomic status over the course of the infants' lives and across generations. Inequalities in low birth weight outcomes have been described by socioeconomic position and there is a large body of evidence showing a substantially higher risk of low birth weight in infants born to poor mothers. Health insurance or coverage is a proxy of socioeconomic position. Higher risk of low birth weight is observed in uninsured infants attended in public hospitals.

The implications of the COVID-19 pandemic for socioeconomic health inequalities are just beginning to be studied. We searched MEDLINE from inception to May 10, 2021, using the search terms "infant*," "newborn*," "neonat*" AND "low birth weight," "very low birth weight," "extremely low birth weight" AND "socio*," "econom*," "deprivation," "poverty," "poor," "health," "insur*," "coverage," "income," "disparit*," "inequit*," "inequalit*." There are no published studies specifically investigating low birth weight risk inequalities by socioeconomic position during COVID-19 pandemic.

Added value of this study

To our best knowledge, this is the first study to explore socioeconomic inequalities in low birth weight risk during COVID-19 pandemic. In this study, we present a large sample of infants who were born in ten hospitals, four public and six private, to assess socioeconomic inequalities in low birth weight risk during the first wave of the COVID-19 pandemic in Argentina. We observed that during the first wave of COVID-19 pandemic compared with the prepandemic period, socioeconomic inequalities in very low birth weight risk decreased between uninsured infants born in public hospitals and those born in private hospitals with health insurance.

Implications of all the available evidence

This study shows evidence that economic mitigation measures during the COVID-19 pandemic, particularly government financial support through universal pregnancy allowance and emergency family income programs benefited most vulnerable pregnant women attended in public hospitals with a decrease in inequalities in VLBW risk by reducing socioeconomic insecurity.

Public health policies must emphasize the importance of antenatal care and to support health care services for pregnant women and infants at risk of low birth weight.

National governments should consider how to financially support economically vulnerable and socially disadvantaged pregnant women by considering that each of these vulnerabilities magnifies the risks in all contexts.

1. Introduction

Socioeconomic inequalities in health are pervasive, particularly in low and middle-income countries. Low birth weight (LBW) is an important measure of health, because it is a leading risk factor for infant mortality as well as a marker for subsequent child morbidity among infants who survive; it is also an important predictor of health and socioeconomic status over the course of the infants' lives and across generations [1-3].

Poor women and infants experience persistent inequalities in birth outcomes. Infants born in public hospitals are 25% more

likely to be born with low weight and 50% more likely to be born with very low birth weight (VLBW) in Argentina, where there is clear evidence of a socioeconomic gradient in LBW between infants born in public hospital and private hospitals [4].

Not only does the coronavirus disease 2019 (COVID-19) represent a pandemic and global health crisis, it is also a socioeconomic disaster. The COVID-19 pandemic threatens to exacerbate existing LBW and VLBW risk inequalities, yet worldwide data are insufficient to inform this critical concern. The COVID-19 pandemic may be replicating existing inequality structures and markedly harming poor women and infants. Poor women are more likely to experience pandemic-related psychological, social, and economic impacts during pregnancy [4-11].

The impact of COVID-19 has been significant in Argentina. During 2020, the country suffered a 9.9% decline in gross domestic product, the largest retraction since 2001. Urban poverty in Argentina increased from 35.5% in 2019 to 42.3% of the population in 2020, with 10.5% extreme poverty and 57.7% child poverty. To deal with this situation, Argentina has prioritized social spending through various programs, including the universal pregnancy allowance and emergency family income granted exclusively to low-income pregnant women and their families in proven situations of formal unemployment [12,13].

To date, research has not adequately studied the association of the COVID-19 pandemic with LBW risk from a health equity perspective. For this reason, we conducted a difference-in-difference (DID) analysis to compare differences between public hospitals and private health coverage, a proxy for socioeconomic position, in LBW risk during the first wave of the pandemic with the preceding year [14]. We hypothesized that the emergency economic COVID-19 mitigation measures implemented in Argentina, particularly those measures to protect the most vulnerable that prioritized social spending through various programs, including the universal pregnancy allowance and emergency family income, cash transfer programs that reach all low-income pregnant women and their families, had a positive impact on LBW outcomes in public hospitals.

2. Methods**2.1. Study design, data source and participants**

This is a multicenter cross-sectional study. The cohorts were defined using data manually extracted from the medical records of ten hospitals (four public and six private) in the city of Córdoba, Argentina. All singleton live birth infants weighing 500 g or more at the ten hospitals from March 20 to July 19, 2020 (pandemic cohort) and all singleton live birth infants weighing 500 g or more from March 20 to July 19, 2019 (prepandemic cohort) were included in the study (Argentinean National Guidelines advise against active management of infants born weighing < 500 g). Positive mother for SARS-CoV-2 virus at time of delivery, multiple pregnancies and infants with major congenital malformations, genetic syndromes or congenital infections were excluded. All newborns are treated locally including all complex surgery and cardiovascular interventions.

We followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline for cross-sectional studies.

This study used anonymized and deidentified data; fulfilling data protection Argentine regulations (LN No. 25326/2000). Studies based on medical records do not require further Ethics Committee approval to comply with Argentine regulations (LP No. 9694/2009).

3. Outcomes

The primary outcomes included rates of LBW, VLBW and extremely low birth weight (ELBW) and the secondary outcomes included rates of preterm birth (PTB), small for gestational age (SGA), neonatal mortality (NM) and stillbirths.

LBW was defined as a birth weight of less than 2500 g as per WHO and further categorized into VLBW (< 1500 g) and ELBW (< 1000 g) [15].

Preterm birth (PT) was defined as birth before 37 completed weeks of gestation [15].

Small for gestational age (SGA) was defined as a birth weight below the 10th percentile for GA according to INTERGROWTH-21st growth standards [15].

NM was defined as one infant death during the first 28 completed days of life during each studied period per 100 live births [15].

Stillbirth was defined according to the WHO as fetal death after 22 completed weeks of gestation or weighing at least 500 g during each studied period per 100 live births [15].

4. Exposures

The primary exposure was the first wave of the COVID-19 pandemic defined as the period between March 20 and July 19, 2020, during which all the Argentinean population was subjected to isolation at home, interpersonal separation and restriction of movement in order to reduce the risk of infecting themselves or other persons, and the national government implemented emergency economic mitigation measures through various programs including universal pregnancy allowance and emergency family income [16].

The secondary exposure was health coverage. Health coverage is divided into public and private coverage. Free public health coverage comprises the public hospital system under the Ministry of Health; it serves the poorest segment of the population without formal work or social security. Private hospitals are for-profit or non-profit privately funded institutions, which serve formal workers and their families with social security as well as patients with private health insurance or those who pay for services out of pocket. In Argentina, some pregnant women with health insurance, particularly among low-income unskilled formal workers, seek care in public hospitals; this data was included separately for analysis.

5. Covariates

The following covariates were used to identify potential confounders for LBW. Gestational age was estimated based on the date of the last menstrual period, parity was characterized as first versus higher-order birth (nulliparous, multiparous), maternal age at birth in years (< 20 years, > 35 years), marital status at time of birth (single, married), maternal education in years (< 12 years, \geq 12 years), cigarette smoking at time of delivery (yes or no), prepregnancy body mass index (BMI), defined as weight in kilograms divided by the square of height in meters (< 18.5 kg/m², \geq 30.0 kg/m²), and prenatal care (at least eight prenatal care visits, yes or no) [15].

To test the possibility of residual confounding of between-hospitals effects on primary outcomes, we did an analysis to disentangle between-hospitals effects. A variable was created under the name of proportion of neonatal mortality showing what proportion of infants attended at each hospital died during the first 28 completed days of life. To create this variable, the proportion of NM at a hospital was calculated and ordered into quartiles, with one being hospitals with the lowest proportion of NM and four being the highest (first quartile < 0.7%, second quartile 0.7 to < 1.1%,

third quartile 1.1 to 1.5% and fourth quartile > 1.5% neonatal mortality). We then added this variable to log binomial multivariable regression models to estimate an adjusted DID estimator for each primary outcome.

6. SARS-CoV-2 test

Reverse transcription polymerase chain reaction tests for the presence of SARS-CoV-2 virus were performed using samples obtained via nasopharyngeal swab on all pregnant women at the time of hospital admission for delivery.

7. Data analysis

Assuming a previous risk difference of 1.0%, the study was designed to have 80% power and 5% significance to detect a subsequent additional difference of 0.1% risk of LBW in infants born in public hospitals compared with infants born in private hospitals in the DID analysis.

We describe the absolute (n) and relative frequency (%) of baseline neonatal, maternal and fetal characteristics. To compare outcomes between prepandemic and pandemic cohorts by public or private health coverage, we used the χ^2 test. Two-sided p values of less than 0.05 were considered to indicate statistical significance.

We used log binomial regression to estimate a DID equation with main effects for public versus private coverage risk difference, pandemic vs. prepandemic cohort risk difference, and an interaction term representing the DID estimator. The DID estimator estimates the additional disparity resulting from the pandemic beyond disparities that had previously existed. DID is usually implemented as an interaction term between time and treatment group dummy variables in a regression model and is calculated with the equation $Y = \beta_0 + \beta_1 \times [\text{Public}] + \beta_2 \times [\text{Year}] + \beta_3 \times [\text{Public} \times \text{Year}] + \beta_4 \times [\text{Gestational age}] + \beta_5 \times [\text{Small for gestational age}] + \beta_6 \times [\text{Parity}] + \beta_7 \times [\text{Maternal age}] + \beta_8 \times [\text{Marital status}] + \beta_9 \times [\text{Maternal education}] + \beta_{10} \times [\text{Pregnancy body mass index}] + \beta_{11} \times [\text{Prenatal smoking}] + \beta_{12} \times [\text{Prenatal care}] + \beta_{13} \times [\text{Proportion of neonatal mortality}] + \varepsilon$. We estimated multivariable models adjusting DID estimates for gestational age, small for gestational age, parity, maternal age, marital status, maternal education, prepregnancy body mass index, and prenatal smoking, prenatal visits and proportion of neonatal mortality. The DID approach is typically robust to confounding given that the balance of covariates between groups is constant over time. In multivariable analyses, we excluded observations with missing maternal characteristic values (< 1%). The difference-in-difference was considered as statistically significant if the 95% CI did not overlap zero [17]. Analyses were conducted using R software version 4.0.2.

8. Role of the funding source

There was no funding source for this study. All authors had full access to all data in the study and had final responsibility for the decision to submit for publication.

9. Results

A total of 16419 infants were born in the ten studied hospitals from March 20 to July 19, 2019 (prepandemic period) and from March 20 to July 19, 2020 (pandemic period). 46 (0.3%) of 16373 were mothers positive for SARS-CoV-2, 157 (0.9%) were multiple pregnancies, 239 (1.4%) were major congenital malformations, genetic syndromes or congenital infections and 48 (0.3%) were missing maternal data, resulting in a final sample of 15929 infants (Fig. 1).

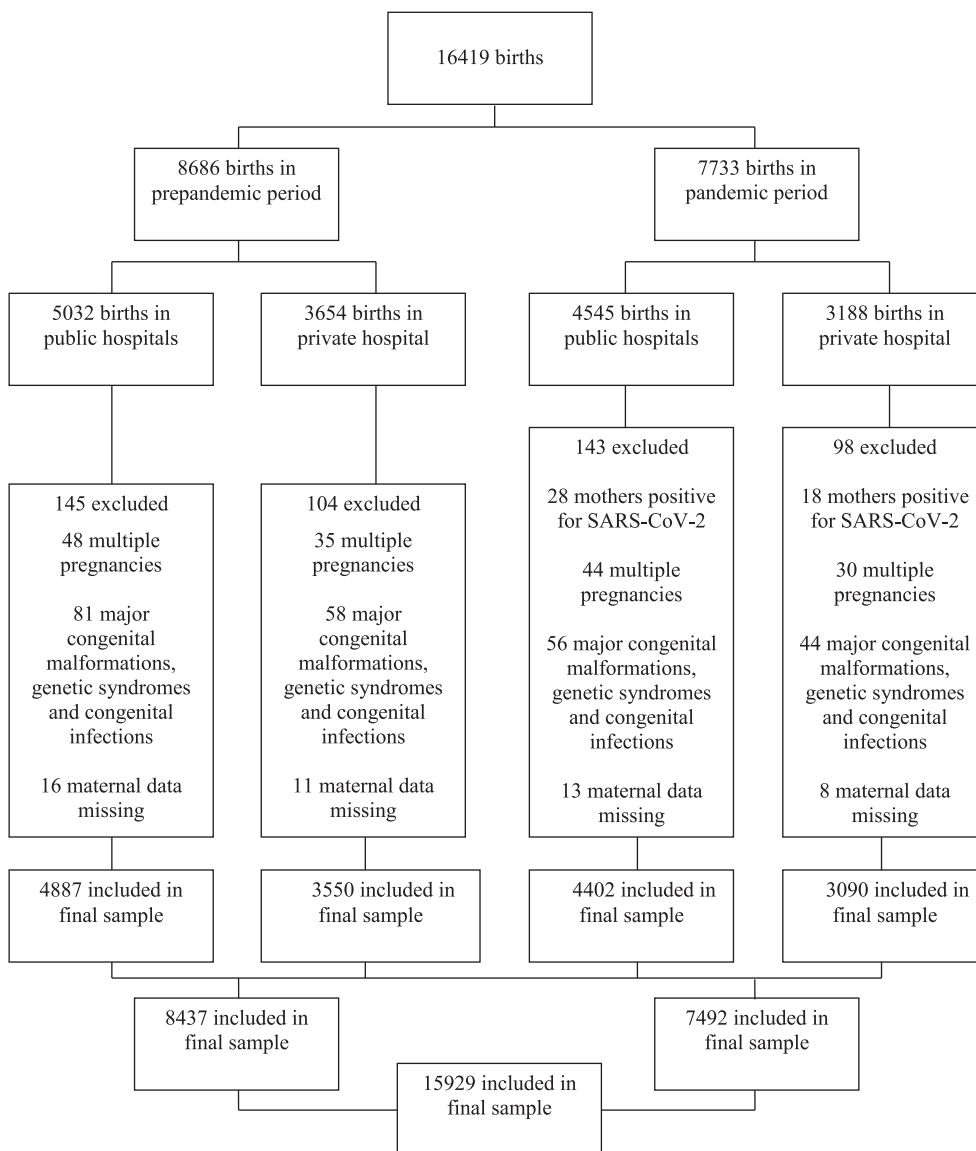


Figure 1. Flow chart of sample size

The infants' characteristics by health coverage and pre-pandemic and pandemic periods are shown in Table 1. Of 8437 infants born in the pre-pandemic period, 4887 (57.9%) were in public hospitals and 3550 (42.1%) in private hospitals. The pandemic cohort comprised 7492 infants, 4402 (58.7%) born in public hospitals and 3090 (41.3%) in private hospitals. The risks of PT (< 37 weeks of gestational age) and SGA did not differ significantly in public compared with private hospitals in pre-pandemic and pandemic periods. In pre-pandemic period the risks of LBW, VLBW, ELBW and NM were significantly higher in public compared with private hospitals, while in pandemic period the risks of LBW, VLBW, ELBW and NM showed no significant differences between public and private hospitals.

Maternal and fetal characteristics are shown in Table 2. The risk of nulliparity, maternal age < 20 years, maternal age > 35 years, single mother, maternal education < 12 years, prepregnancy BMI < 18.5 kg/m², prepregnancy BMI ≥ 30.0 kg/m², prenatal smoking and prenatal visits differ significantly in public compared with private hospital in pre-pandemic and pandemic periods, while the risk of stillbirths did not differ significantly in public compared with private hospital in pre-pandemic and pandemic periods.

There were no significant differences in the number of health-insured births that occurred in public hospitals comparing the pre-pandemic and pandemic periods (2551 of 4887 [30.0%] vs. 1325 of 4402 [30.1%] respectively, p 0.93).

The risk of LBW was 10.3% (502 of 4887) among public hospitals and 8.3% (295 of 3550) among private hospitals during the pre-pandemic period, and 9.3% (411 of 4402) among public hospitals and 9.2% (284 of 3090) among private hospitals in the pandemic period. The adjusted DID estimator was -1.7% (95% CI -3.6, 0.1) cases, indicating no significant changes for public versus private inequality in pandemic compared with pre-pandemic period. The risk of VLBW was 2.7% (132 of 4887) among public hospitals and 1.8% (63 of 3550) among private hospitals during the pre-pandemic period, and 2.0% (91 of 4402) among public hospitals and 2.3% (72 of 3090) among private hospitals in the pandemic period. The adjusted DID estimator was -1.1% (95% CI -2.5, -0.2) cases. The DID estimator decreased significantly for public versus private inequality in pandemic compared with pre-pandemic period. The risk of ELBW was 0.9% (43 of 4887) among public hospitals and 0.5% (19 of 3550) among private hospitals during the pre-pandemic period, and 0.6% (29 of 4402) among public hospitals and 0.4% (14

Table 1
Infant characteristics by health coverage and prepandemic and pandemic period

Characteristic	Prepandemic period ^a n 8437			Pandemic Period ^{**} n 7492		
	Public [#] n(%)	Private [#] n(%)	p	Public [#] n(%)	Private [#] n(%)	p
Births	4887 (57.9)	3550 (42.1)		4402 (58.7)	3090 (41.3)	
Preterm births (< 37 weeks)	475 (9.7)	308 (8.7)	0.13	398 (9.0)	274 (8.0)	0.91
Small for gestational age (Birth weight $< 10^{\text{th}}$ percentile)	264 (5.4)	178 (5.0)	0.44	225 (5.1)	167 (5.4)	0.60
Low birth weight ($< 2500\text{g}$)	502 (10.3)	295 (8.3)	$<$	411 (9.3)	284 (9.2)	0.91
Very low birth weight ($< 1500\text{g}$)	132 (2.7)	63 (1.8)	0.01	91 (2.0)	72 (2.3)	0.42
Extremely low birth weight ($< 1000\text{g}$)	43 (0.9)	19 (0.5)	0.04	29 (0.6)	14 (0.4)	0.30
Neonatal deaths	60 (1.2)	21 (0.6)	0.01	25 (0.6)	12 (0.4)	0.30

* From March 20 to July 19, 2019.

** From March 20 to July 19, 2020.

Percentages were calculated on the number of births of each column. The sum of each column may differ from the number of births because normal infants were not included in the table and some characteristics may overlap.

Table 2
Maternal and fetal characteristics by health coverage and prepandemic and pandemic periods

Characteristic	Prepandemic period ^a n 8437			Pandemic Period ^{**} n 7492		
	Public [#] n(%)	Private [#] n(%)	p	Public [#] n(%)	Private [#] n(%)	p
Births	4887	3550		4402	3090	
Nulliparity	1709 (35.0)	1740 (49.0)	< 0.00	1541 (35.0)	1514 (49.0)	< 0.00
Maternal age < 20 years	552 (11.3)	201 (5.7)	< 0.00	520 (11.8)	182 (5.9)	< 0.00
Maternal age > 35 years	733 (15.0)	764 (21.5)	< 0.00	655 (15.0)	658 (21.3)	< 0.00
Single mother	720 (15.0)	266 (7.5)	< 0.00	638 (14.5)	224 (7.2)	< 0.00
Maternal education < 12 years	982 (20.1)	357 (10.1)	< 0.00	902 (20.5)	317 (10.3)	< 0.00
Prepregnancy BMI [§] < 18.5 kg/m ²	58 (1.2)	25 (0.7)	0.03	53 (1.2)	22 (0.7)	0.04
Prepregnancy BMI [§] ≥ 30 kg/m ²	1587 (32.5)	901 (25.4)	< 0.00	1439 (32.7)	794 (25.7)	< 0.00
Prenatal smoking	968 (19.8)	351 (9.9)	< 0.00	872 (19.8)	306 (9.9)	< 0.00
Prenatal Care < 8 Visits	259 (5.3)	94 (2.6)	< 0.00	291 (6.6)	102 (3.3)	< 0.00
Stillbirths	36 (0.7)	28 (0.8)	0.69	32 (0.7)	23 (0.7)	0.89

* From March 20 to July 19, 2019.

** From March 20 to July 19, 2020.

§ BMI: body mass index.

Percentages were calculated on the number of births in each column. The sum of each column may differ from the number of births because normal pregnancies were not included in the table and some characteristics may overlap.

of 3090) among private hospitals in the pandemic period. The adjusted DID estimator was -0.1% (95% CI $-0.7, 0.4$) fewer cases, indicating no change for public versus private inequality in pandemic compared with prepandemic period (table 3).

There were no significant changes in inequalities of PTB, SGA, NM and stillbirth risks associated with COVID-19 pandemic when comparing public hospitals with private hospitals (Table 4).

The regression coefficients of all covariates with their 95% CIs are shown in the Appendix (see Table A1).

To separate the between-hospitals effect of socioeconomic inequalities, we assessed the effect of the proportion of neonatal mortality at a hospital as an additional between-hospitals variable. In the adjusted log binomial regression analysis, this between-hospitals variable was not significant, and the inclusion of the between-hospital variable (proportion of neonatal mortality) did

not attenuate the decreased disparities between public and private hospitals in VLBW risk difference of -1.1 95% CI $-2.5, -0.1$.

10. Discussion

In this study, we present a large sample of infants who were born in ten hospitals, four public and six private, to assess socioeconomic inequalities in LBW risk during the first wave of the COVID-19 pandemic in Argentina.

There is little scientific evidence to support the notion that social interventions prevent low birth weight, particularly among the socioeconomically disadvantaged population in developing countries. The mandatory lockdown offers a unique opportunity to evaluate whether some lockdown elements such as economic mitigation measures potentially prevent low birth weight. We chose low

Table 3

Difference-in-difference analysis of public vs. private health coverage inequalities in low birth weight, very low birth weight and extremely low birth weight in pre-pandemic period compared with pandemic period

Outcome	Prepandemic period(March 20 to July 19, 2019)			Pandemic period(March 20 to July 19, 2020)			Risk difference prepandemic periodvs. pandemic period% (95% CI)
	Denominator	Cases,No.	Risk,%	Denominator	Cases,No.	Risk,%	
Low birth weight							
Births	8437			7492			
Private	3550	295	8.3	3090	284	9.2	0.9 (-0.5, 2.2)
Public	4887	502	10.3	4402	411	9.3	-1.0 (-2.1, 0.3)
Difference*			2.0			0.1	-1.8 (-3.6, 0.0)
Adjusted difference**							-1.7 (-3.6, 0.1)
Very low birth weight							
Births	8437			7492			
Private	3550	63	1.8	3090	72	2.3	0.5 (-0.1, 1.2)
Public	4887	132	2.7	4402	91	2.0	-0.6 (-1.2, -0.0)
Difference*			0.9			-0.3	-1.2 (-2.1, -0.3)
Adjusted difference**							-1.1 (-2.5, -0.1)
Extremely low birth weight							
Births	8437			7492			
Private	3550	19	0.5	3090	14	0.4	-0.1 (-0.4, 0.2)
Public	4887	43	0.9	4402	29	0.6	-0.3 (-0.6, 0.1)
Difference*			0.3			0.2	-0.1 (-0.6, 0.3)
Adjusted difference**							-0.1 (-0.7, 0.4)

* Binomial regression coefficient.

** Binomial regression coefficient adjusted for gestational age (continuous), small for gestational age (yes, no), parity (nulliparous, multiparous), maternal age (continuous), marital status (single, married), maternal education (continuous), prepregnancy body mass index (continuous [BMI; calculated as weight in kilograms divided by height in meters squared]), prenatal smoking (yes or no), prenatal care (< 8 visits, ≥ 8 visits), and proportion of neonatal mortality (1,2,3,4).

Table 4

Difference-in-difference analysis of public vs. private health coverage inequalities in preterm birth, small for gestational age, neonatal deaths and stillbirths in pre-pandemic period compared with a pandemic period

Outcome	Prepandemic period(March 20 to July 19, 2019)			Pandemic period(March 20 to July 19, 2020)			Risk differenceprepandemic periodvs. pandemic period% (95% CI)
	Denominator	Cases,No.	Risk,%	Denominator	Cases,No.	Risk,%	
Preterm birth							
Births	8437			7492			
Private	3550	308	8.6	3090	274	8.9	0.3 (-1.1, 1.7)
Public	4887	475	9.7	4402	398	9.0	-0.7 (-1.9, 0.5)
Difference*			1.1			0.1	-1.0 (-2.7, 0.9)
Adjusted difference*							-0.9 (-2.5, 0.7)
Small for gestational age							
Births	8437			7492			
Private	3550	178	5.0	3090	167	5.4	0.4 (-0.7, 1.5)
Public	4887	264	5.4	4402	225	5.1	-0.3 (-1.2, 0.6)
Difference*			-0.4			-0.3	0.7 (-2.1, 0.7)
Adjusted difference**							0.6 (-2.0, 0.5)
Neonatal deaths							
Births	8437			7492			
Private	3550	21	0.6	3090	12	0.4	-0.2 (-0.5, 0.1)
Public	4887	60	1.2	4402	25	0.6	-0.6 (-1.0, -0.3)
Difference*			0.6			0.2	-0.4 (-1.0, 0.0)
Adjusted difference**							-0.3 (-1.0, 0.0)
Stillbirths							
Births	8437			7492			
Private	3550	28	0.8	3090	23	0.7	-0.1 (-0.5, 0.4)
Public	4887	36	0.7	4402	32	0.7	0.0 (-0.3, 0.3)
Difference*			-0.1			0.0	0.1 (-0.5, 0.6)
Adjusted difference**							0.0 (-0.4, 0.5)

* Binomial regression coefficient.

** Binomial regression coefficient adjusted for gestational age (continuous), small for gestational age (yes, no), parity (nulliparous, multiparous), maternal age (continuous), marital status (single, married), maternal education (continuous), prepregnancy body mass index (continuous [BMI; calculated as weight in kilograms divided by height in meters squared]), prenatal smoking (yes or no), prenatal care (< 8 visits, ≥ 8 visits), and proportion of neonatal mortality (1,2,3,4).

birth weight as the primary outcome of this study because it represents the most sensitive indicator of the intrauterine growth process, and it is well documented that even phases of a few weeks of stress during pregnancy can lead to a decrease in birth weight [4-11].

We observed that during the first wave of COVID-19 pandemic compared with prepandemic period, socioeconomic inequalities in VLBW decreased between infants born in public hospitals and those born in private hospitals.

We used health insurance status (health coverage) as a proxy for socioeconomic position, with evidence of higher risk of LBW and VLBW in infants born in public hospitals [14]. Although health insurance status and place of birth (public or private) are plausible proxies for socioeconomic status and are used given their availability, neither perfectly captures the mother and child's actual socioeconomic position. We cannot exclude the fact that more marked disparities exist by socioeconomic position, and potentially mediate the differential outcomes we observed in public and private hospitals. It should also be noted that other infrastructural, operational, and educational aspects may influence the outcome disparities between public and private hospitals, such as: equipment, facilities, and medical resources, quality of care, number of deliveries per year, mortality, training programs for residents, and university affiliation.

Better markers of socioeconomic status are needed in research to explain the role of socioeconomic position in health outcomes and understand the mechanism of inequality. On the other hand, the free public health system in Argentina acts as a financial instrument that equalizes access to care without burdening low-income families financially. Thus, the presence of free public health coverage improves access to care and reduces inequality.

The DID approach is typically robust to confounding given that the balance of covariates between treatment groups is constant over time; however some of our findings could be related to the quality of care received in different hospitals [17]. The inequalities described in previous studies of newborns are driven in part by differences in neonatal specific outcomes and process of care quality. In our study, an adjusted DID log binomial multivariable analysis that modeled differences in quality of care effect, considered in terms of the proportion of neonatal mortality between hospitals, did not suggest this was a significant contributor to disparate outcomes.

VLBW is a significant emotional, health, social and economic issue for the affected infants, their families, and society [18]. Preterm birth and VLBW are a major public health concern worldwide and are the leading causes of neonatal disease and death. Consequently, any prevention of LBW is a key factor in reducing perinatal morbidity and mortality [19].

Our findings should be considered in the context of a current hypothesis that COVID-19 lockdown has lessened VLBW risk [20-22]. The reasons for the increase in infant weight at birth during the COVID-19 pandemic are still unclear. Researchers have proposed potential reasons for the decrease in VLBW during the COVID-19 pandemic, such as reduced working hours, reduced somatic and emotional stress of work, increased family support, reduced load of infections, better nutrition and government financial support [23,24]. We speculate that the emergency economic COVID-19 mitigation measures such as the mandatory lockdown and government financial support through universal pregnancy allowance and emergency family income programs particularly benefit most vulnerable pregnant women attended in public hospitals with decrease inequalities in VLBW risk by reducing socioeconomic insecurity. A recent study reported that, during the COVID-19 pandemic, women gained significantly more weight potentially related to a decrease in physical activity and an increase in nutritional intake, which might have resulted in increased gesta-

tional weight gain. The analysis clearly showed that the gestational weight gain was significantly associated with birth weight and gestational length during the pandemic period [21]. Possibly, mothers attended in public hospitals in our study benefited from better nutritional intake as food insecurity was reduced through government emergency financial assistance programs. During the pandemic period, a decrease in the number of antenatal visits was observed in our study. This could have affect birth weight mainly due to the potential under-diagnosis of intrauterine growth restriction.

Socioeconomic crises, such as the global crisis of 2008, have led to reduced mean birth weight in several countries such as Spain, Greece, Portugal, Iceland, Japan, Argentina, Brazil and the USA [4-11]. We have observed an increased trend in the risk of LBW and VLBW among pregnant women attended in private hospitals between the prepandemic period and the first wave COVID-19 pandemic period, although it is not statistically significant. We speculate that this observation may be because any benefit from COVID-19 mitigation policies may be less prevalent in pregnant women with formal employment, who are more likely to be essential workers and to experience a higher risk of COVID-19 pandemic-related job stress, anxiety and insecurity. The change of employment status during the pandemic could have adversely affected the perinatal outcomes in pregnant women who lost their jobs [12].

Paradoxically, the higher risk of LBW and VLBW in infants born in private hospitals may have reduced the inequality gap with respect to those born in public hospitals, due to increased job stress and the relative impoverishment of working mothers with health insurance served in private hospitals. We speculate that this observation should be taken into account to extend the government financial aid plans and mitigation policies to pregnant women with formal jobs but who at the same time, suffer COVID-19 pandemic-related high job stress and insecurity. Another possible explanation for the increase in LBW and VLBW in private hospitals is that some infants were probably cases of intrauterine growth restriction whose intensive care might have been more efficient in private hospitals than in public hospitals, increasing survival in this group and thus increasing the rate of LBW and VLBW given the differences in hospital resources.

We found a significant decrease in the risk of NM in infants born in public hospitals in the pandemic period compared with the prepandemic period, possibly related to the increase in chances of survival resulting from the decreasing inequalities in birth weight. This finding appears to be a solid result supporting the protective effect of the social changes related with pandemic mitigation policies on maternal and neonatal health and wellbeing; however there was no change in public versus private NM inequalities associated with the COVID-19 pandemic. To our knowledge only two studies have addressed the effect of the COVID-19 pandemic on neonatal mortality. One in Israel that does not report changes between pre-lockdown and lockdown periods and another in Nepal that reports an increase in NM during COVID-19 pandemic period [22,25]. These disparities are probably due to cultural, social and economic differences as well as to differences in economic mitigation policies, as well as management and medical care resources, between these countries.

It is possible that some pregnancies have resulted in intrauterine death and that these pregnancies have been classified as fetal deaths. In this study, we did not find significant differences in the incidence of stillbirths during the COVID-19 pandemic period and the same period in the previous year, even adjusting by prenatal visits, and there was no change in public versus private stillbirth inequalities associated with COVID-19 pandemic. This finding is possibly associated with the protective effect of the social changes related to COVID-19 economic mitigation policies on maternal health and wellbeing. In concordance with our results, other studies have not reported significant differences in the incidence of

stillbirths during the pandemic period compared with the prepandemic period [26–28]. However, some studies have reported an increment of stillbirths during the pandemic [25,29,30]. The authors of these studies believe that this increase in stillbirths could be a consequence of life changes induced by the lockdown and in particular caused by reduced prenatal visits to hospital due to the fear of contracting COVID-19. It should be noted that none of these studies have adjusted stillbirths by prenatal visits.

11. Limitations

The limitations of our study require consideration. First, a major limitation is the cross-sectional study design based on medical records with the potential risk of data loss. In this sense, the causal inference between exposure to economic mitigation policies during the COVID-19 pandemic and decreased inequalities in VLBW should be considered with caution. In this study, only 48 of 16419 (0.3%) medical records were excluded due to missing data. Future prospective studies are needed to clarify potential causalities. Second, although misclassification or residual and unmeasured confounding may have affected our results, we are certain that our data accurately reflect the birth outcomes in the city of Córdoba, Argentina, because they are based on reliable mandatory reports drawn up according to uniform international standards established by the Argentinean National Mother and Child Health Department, applied independently before and during the COVID-19 pandemic. Third, it is possible that many women, especially those with a higher risk of adverse outcomes, either decided not to become pregnant or were unable to become pregnant during the pandemic due to the unstable external environment. The possibility of selection bias cannot be ruled out without further research. Fourth, the number of prenatal visits decreased during the COVID-19 pandemic, which may have reduced the chances of detecting pathologies during pregnancy, possibly increasing fetal deaths and decreasing preterm births. Fifth, the referral patterns could have changed during the COVID-19 pandemic, varying the incidence of LBW or VLBW. Due to the restrictions during the pandemic, several infants born to high risk pregnancies who are usually delivered at referral centers could have been born at local hospitals because they were unable to reach level III centers. This could also have had an impact on the decrease in the proportion of LBW and VLBW infants born at the public hospitals included in our sample. In patients born at private hospitals, the pattern of referrals may be different and the possibility to travel to reach level III hospitals may be easier, which would therefore not have decreased the number of births at the centers included in the present study. Sixth, it is likely that some stillbirths were unreported. If this occurred, it would most likely be due to systematic under-reporting and would be similarly distributed in the pre-pandemic and pandemic periods. The DID approach is typically robust to confounding given that the balance of covariates between periods is constant over time.

One of the strengths of this study is the availability of detailed maternal and neonatal epidemiologic data from almost all infants born in the city of Córdoba. Córdoba is the second most populated city in Argentina and its population is highly representative of the urban population nationwide. We are able to identify and adjust for the presence of multiple perinatal confounders, which are particularly significant covariates.

In conclusion, in this cross-sectional study, we found evidence of decreased disparities between infants born in public hospitals and private hospitals in VLBW risk. Our findings suggest that measures that prioritize government social spending to protect the most vulnerable pregnant women contributed to better birth outcomes and provide insights into interventions to reduce adverse birth outcomes in Argentina and other countries throughout the world.

Contributors

EC conceptualized and designed the study, coordinated and supervised data collection, carried out the final data analyses, drafted the initial manuscript, and reviewed and revised the final manuscript. MEG-F, MDC, AJP, CM, IS-B, VB, GG, ME, SDB-P,DGP, LAA, RDP, AR, JIB, MBV, MJM, MF, GCM, HP and MR-R designed the data collection instruments, manually collected data, carried out the initial analyses, and reviewed and revised the manuscript for important intellectual content. All authors have approved the final manuscript as submitted.

Declaration of interest

The authors declare no competing interests.

Data sharing

The datasets generated during the present study are available to others upon reasonable request via email to the corresponding author.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.lana.2021.100049.

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