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CORRESPONDENCE

Neonatal outcomes during the COVID-19 pandemic in New York City

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New York City (NYC) emerged as the epicenter of the COVID-19 pandemic in the United States, prompting lockdown measures including school closings, stay-at-home orders, and a shift to working from home.[1] These public health interventions were initially instituted to curb transmission of the virus, but have provided insights into associations between lockdown measures and health outcomes. Several reports linked COVID-19 lockdown measures to reduced rates of preterm birth, providing possible mechanisms for preterm birth prevention.[2–6] To date, this link has not been assessed in NYC, one of the hardest hit and most populous, diverse cities in the United States. Furthermore, neonatal intensive care unit (NICU) admissions, which are related to but not exclusively modified by preterm birth rates, may also be impacted by lockdown measures. Both of these neonatal outcomes may also be influenced by NYC phase one reopening, which was associated with additional policy and behavioral changes. We, therefore, assessed if the NYC COVID-19 lockdown measures or NYC phase one reopening were associated with changes in preterm birth or NICU admission rates in a large and diverse cohort at the Mount Sinai Hospital.

There were 66,363 neonates born at the Mount Sinai Hospital between January 1, 2012 and November 25, 2020. We excluded 22,400 neonates, the majority of whom had a primary residence outside NYC and may have experienced different lockdown measures and reopening timelines (Supplementary Fig. 1). We also excluded 3430 neonates from multiple births and 184 neonates born to COVID-19 positive mothers, which are potential risk factors for preterm birth.[2] We defined preterm birth as gestational age (GA) <37 weeks and late term as >41 + 6 weeks, excluding late-term neonates from our analysis. Our final cohort totalled 43,963 singleton neonates, including 3348 live births since the implementation of COVID-19 lockdown measures (Supplementary Fig. 1). Data were obtained from electronic health records (Supplementary Fig. 1) and research was approved by the Mount Sinai Institutional Review Board. We used March 16, 2020 as the first calendar date of lockdown measures because it had the largest drop in mobility and was the date of NYC's public school system closure (Supplementary Fig. 2).[1] We used June 8, 2020 as the date of reopening because it was the official date of the implementation of NYC phase one reopening.

We used a quasi-experimental difference-in-difference (DiD) logistic regression to test for associations between NYC lockdown measures or reopening and our two primary outcomes, preterm birth and NICU admission rates (model in Supplementary Methods). We compared 1-, 2-, and 3-month epochs before and after the calendar dates of the two pandemic response measures in 2020 to the same short time periods in 2012–2019. Comparing the trends of these short time intervals to the trends in prior years limits the influence of confounding variables, such as seasonal preterm birth changes. We assessed these three windows (±1, ±2, and ±3 months) before and after each calendar date to test for sensitivity to time interval choice; for the reopening analysis, we limited the largest window to the start date of lockdown measures (i.e., 2.75 months before and after reopening). The total births, preterm births, and NICU admissions in each of these analyses is enumerated in Supplementary Table 2. We conducted sensitivity analyses excluding data within 0.1 and 0.2 months (3 and 6 days, respectively) of each calendar date to test for the robustness of date choice. To evaluate the impact of excluding neonate–mother pairs with missing GA, we conducted another sensitivity analysis using only data from 2017 to 2020, during which GA missingness was <1%. All statistical analyses were performed in R 3.5.1.

The characteristics of our cohort of singleton neonates born to mothers who were negative for COVID-19 during pregnancy are shown in Supplementary Table 1. In our 2020 cohort, 38% of neonates were White, 13% were Black, and 6.1% were Asian (Supplementary Table 1). In the 3 months before and after the implementation of NYC lockdown measures on March 16, 2020, preterm birth rates increased from 6.2 to 8.0% (Fig. 1, odds ratio (OR) = 1.27, 95% confidence interval (CI) = 0.92–1.74). In 2012–2019, we observed an increase in preterm births from 6.9 to 7.3% (OR = 1.08, 95% CI = 0.96–1.20). This was comparable to the change in 2020 as determined by a DiD logistic regression (Fig. 1, $\beta_{DID} = 0.16$, $P_{DiD} = 0.35$). NICU admissions increased from 6.9 to 9.1% in 2020, which was also not significantly different from the change in 2012–2019 (Fig. 1, 6.1–6.4%, $\beta_{DID} = 0.28$, $P_{DiD} = 0.09$). Results for both preterm births and NICU admission rates were consistent when using shorter time windows around the implementation date of lockdown measures (Fig. 1, $\beta_{DID} = 0.24–0.44$, $P_{DiD} = 0.11–0.23$).

We also compared changes in preterm births and NICU admissions before and after NYC phase one reopening on June 8, 2020, to the same time period in 2012–2019. Using the largest time window before and after June 8, we observed a decrease in preterm births from 8.3 to 4.6% in 2020 (Fig. 2, OR = 0.53, 95% CI = 0.37–0.74). This was significantly different from 2012 to 2019 based on DiD logistic regression (Fig. 2, $\beta_{DID} = -0.56$, $P_{DiD} = 0.0028$), when preterm birth rates only decreased from 7.4 to 6.8% (Fig. 2, OR = 0.92, 95% CI = 0.83–1.03). Changes in preterm birth rates in 2020 were also significantly different from 2012 to 2019 when restricting to shorter time windows around reopening (Fig. 2, ±1 month, $\beta_{DID} = -0.62$, $P_{DiD} = 0.049$; ±2 months, $\beta_{DID} = -0.54$, $P_{DiD} = 0.015$). We observed similar trends for NICU admissions, which decreased from 9.6 to 6.4% in 2020 compared to an increase from 6.4 to 7.1% in 2012–2019 (Fig. 2, $\beta_{DID} = -0.55$, $P_{DiD} = 0.0011$). These NICU admission trends were similar but not statistically significant for smaller time windows (Fig. 2, ±1 month, $\beta_{DID} = -0.32$, $P_{DiD} = 0.27$; ±2 months, $\beta_{DID} = -0.34$, $P_{DiD} = 0.084$). These results were robust to excluding data immediately before and after lockdown measures and reopening, as well as restriction to births since 2017 (Supplemental Fig. 3).

Studies from the Netherlands, Denmark, Ireland, Italy, and Japan demonstrated a reduction in preterm births following the implementation of lockdown measures.[2–6] In contrast, studies from the United States in California and Philadelphia reported no significant change in preterm births after lockdown.[7,8] In our NYC study, we observed comparable rates in preterm birth and NICU

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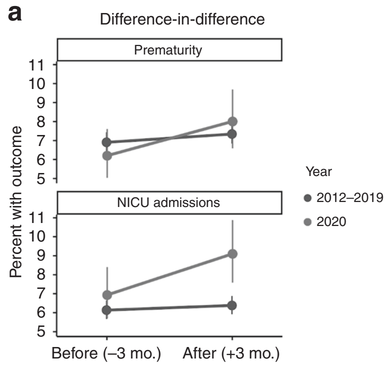
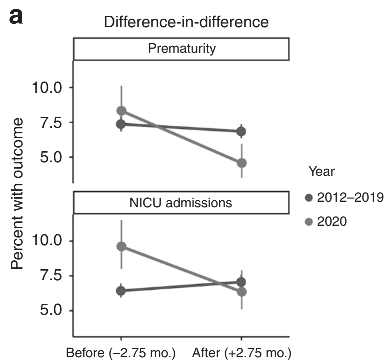


b Sensitivity to month cut-off

Outcome	Month	OR_{2020} (95% CI)	$OR_{2012–2019}$ (95% CI)	β_{DID}	P_{DID}
Premature	±1	1.50 (0.86–2.62)	1.00 (0.83–1.21)	0.40	0.18
	±2	1.41 (0.98–2.03)	1.11 (0.97–1.27)	0.24	0.23
	±3	1.27 (0.92–1.74)	1.08 (0.96–1.20)	0.21	0.21
NICU admission	±1	1.55 (0.94–2.55)	1.00 (0.81–1.23)	0.44	0.11
	±2	1.40 (0.98–1.99)	1.06 (0.91–1.22)	0.28	0.15
	±3	1.38 (1.01–1.87)	1.04 (0.92–1.17)	0.25	0.11

Fig. 1 Comparable changes to previous years in preterm birth and NICU admission rates at the Mount Sinai Hospital after New York City (NYC) implemented lockdown measures. a Change in the percent of preterm births (GA < 37 weeks) (top panel) and NICU admissions (bottom panel) in the 3 months before and after the implementation of COVID-19 lockdown measures (March 16, 2020), compared to those of the same time periods in 2012–2019. **b** Results of the difference-in-difference (DiD) logistic regression that compared the odds ratios (ORs) in 2020 to those in 2012–2019. ORs represent changes in neonatal outcomes after lockdown measures. We observed $P_{DiD} > 0.05$ for all time windows, indicating that changes in both neonatal outcomes were comparable in 2020 to the same time periods in prior years. OR odds ratio, 95% CI 95% confidence interval (lower-upper), β_{DID} DiD coefficient, P_{DID} *p* value of the DiD coefficient.



b Sensitivity to month cut-off

Outcome	Month	OR_{2020} (95% CI)	$OR_{2012–2019}$ (95% CI)	β_{DID}	P_{DID}
Premature	±1	0.55 (0.30–0.99)	1.03 (0.85–1.24)	−0.62	0.049
	±2	0.55 (0.36–0.82)	0.93 (0.82–1.07)	−0.54	0.015
	±2.75	0.53 (0.37–0.74)	0.92 (0.83–1.03)	−0.56	0.0028
NICU admission	±1	0.71 (0.42–1.20)	0.97 (0.80–1.18)	−0.32	0.27
	±2	0.76 (0.53–1.09)	1.07 (0.94–1.23)	−0.34	0.084
	±2.75	0.64 (0.47–0.87)	1.11 (0.99–1.24)	−0.55	0.0011

Fig. 2 Statistically significant reduction in preterm birth and NICU admission rates after the initiation of NYC phase one reopening compared to 2012–2019. a Change in the percent of preterm births (top panel) and NICU admissions (bottom panel) in the 2.75 months before and after NYC phase one reopening (June 8, 2020), compared to those of the same time periods in 2012–2019. **b** Results of the difference-in-difference (DiD) logistic regression that compared the odds ratios (ORs) in 2020 to those in 2012–2019. ORs represent changes in neonatal outcomes after reopening. We observed $\beta_{DID} < 0$ and $P_{DiD} < 0.05$ in preterm birth rates for all time windows, and the largest time window for NICU admissions, indicating that both neonatal outcomes decreased significantly after reopening when compared to same time periods in prior years. OR odds ratio, 95% CI 95% confidence interval (lower-upper), β_{DID} DiD coefficient, P_{DID} *p* value of the DiD coefficient.

admissions after the implementation of lockdown measures when compared to those of the same time period in previous years. Thus far, all reports have observed no change or a reduction in preterm birth, and none have shown increases. Our study also assessed these neonatal outcomes after NYC phase one reopening, where we indeed observed a statistically significant reduction in preterm birth and NICU admission rates compared to trends after the same calendar date in prior years.

Associations between the COVID-19 lockdown and reopening measures with preterm birth are multifactorial, and affected by patient, health system, sociodemographic, and geographical factors. Our results may reflect changes in obstetric care and shifts in health services. For example, changes in the timing of cesarean section or induction in response to maternal or fetal health concerns could impact preterm birth rates.[2] Our observations could also be attributable to a delayed impact of NYC lockdown measures on factors previously implicated in preterm birth, reduced exposure to non-COVID-19 infections, better air quality, and increased hygienic practices.[2] This delay could be specific to NYC, which experienced an overburdened hospital system and exodus during the earliest days of the pandemic in the United States.[1] We were unable to measure stillbirths, an important competing outcome, because the relevant Current Procedural Terminology codes are not currently linked to our electronic health record resource. A comparison with stillbirths in our cohort could also reflect a confounded competing outcome because we were not following a prospective pregnancy cohort, and the cohort of women who had stillbirths at our institution could be different from those who had live births. Small sample size and absence of information on socioeconomic status, neonatal diagnoses, and maternal risk factors, such as age, parity, and other reproductive and medical conditions, also meant that we were unable to measure the impact of these important determinants on our outcomes of interest. A recent, smaller cohort of preterm births in NYC was analyzed and found no differences between racial/ethnic groups.[9] Thus, while we did observe a statistically significant reduction in preterm birth and NICU admission rates after NYC phase one reopening, the mechanisms underlying this change are likely multifaceted and warrant further investigation.

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AUTHOR CONTRIBUTIONS

F.R. and A.S.S. co-led the study. F.R., A.S., K.G., and B.S.G. designed the study. F.R., A.S.S., S.Z., G.N.N., and B.S.G. acquired the data. F.R., A.S.S., and M.S.-F. performed the analyses. G.N.N., S.Z., M.S.-F., E.W.J., and K.G. interpreted the results. F.R., A.S.S., E.W.J., and B.S.G. wrote the manuscript. M.S.-F., S.Z., G.N.N., E.W.J., and K.G. provided critical revisions. E.W.J., K.G., and B.S.G. jointly supervised the work. All authors edited and approved the manuscript.

ADDITIONAL INFORMATION

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