Aust N Z J Obstet Gynaecol 2022; 62: 62–70 ANZJOG
DOI: 10.1111/ajo.13406

ORIGINAL ARTICLE

A decline in planned, but not spontaneous, preterm birth rates in a large Australian tertiary maternity centre during COVID-19 mitigation measures

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Conflicts of Interest: The authors report no conflicts of interest.

Received: 12 January 2021; Accepted: 8 June 2021

Background: Reports from around the world suggest that rates of preterm birth decreased during COVID-19 lockdown measures.
Aims: To compare the prevalence of preterm birth and stillbirth rates during COVID-19 restriction measures with infants born at the same maternity centre during the same weeks in 2013–2019.
Materials and Methods: Deidentified data were extracted from the Mater Mothers' healthcare records database. This is a supra-regional tertiary perinatal centre. Logistic regressions were used to examine singleton live preterm birth rates during the beginning of COVID-19 restrictions (16 March-17 April; 'early'; 6955 births) and during the strictest part of COVID-19 restrictions (30 March-1 May; 'late'; 6953 births), according to gestational age subgroups and birth onset (planned or spontaneous). We adjusted for multiple covariates, including maternal age, body mass index, ethnicity, parity, socioeconomic status, maternal asthma, diabetes mellitus and/or hypertensive disorder. Singleton stillbirth rates were also examined between 16 March–1 May.
Results: Planned moderate/late preterm births declined by more than half during early COVID-19 restrictions compared with the previous seven years (29 vs an average of 64 per 1000 births; adjusted odds ratio 0.39, 95% CI 0.22–0.71). There was no effect on extremely or very preterm infants, spontaneous preterm births, or stillbirth rates. Rolling averages from January to June revealed a two-week non-significant spike in spontaneous preterm births from late April to early May, 2020.
Conclusions: Together with evidence from other nations, the pandemic provides a unique opportunity to identify causal and preventative factors for preterm birth.

KEYWORDS
lockdown, pandemic, pregnancy, premature birth, stillbirth

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INTRODUCTION

The 2020 novel coronavirus (COVID-19)[1] was declared a pandemic by the World Health Organization on March 11, 2020. In Australia, preventative measures, including staying at home if feeling unwell, social distancing, self-isolation for international arrivals, and cancellation of large gatherings were instituted from mid-March.[2] In Queensland specifically, all but essential services were shut down by the end of March, with gradual easing of restrictions commencing in early May.

From a global perspective, the pandemic has resulted in significant reconfiguration and reduction of routine healthcare services. Often, only life-saving and emergency procedures are available with cessation of routine screening programs and elective surgery. Unfortunately, this strategy has resulted in significant unintended outcomes for patients – delay in cancer diagnosis, poor control of chronic cardiovascular and metabolic disorders, and profound psychological stress. However, in maternity care consequences of the imposed restrictions have been mixed. Early reports from some countries suggest that although stillbirth rates increased,[3–5] rates of preterm birth actually decreased.[5–9] It is not clear if there is a similar trend in Australia. The aim of this study was to investigate preterm birth and stillbirth rates during the lockdown period in the largest single tertiary perinatal centre in Queensland.

MATERIALS AND METHODS

This study was performed at the Mater Mothers' Hospital in Brisbane. This is a supra-regional tertiary perinatal centre with ~10 000 births per year. Ethical and governance approvals were obtained from the institution's Human Research Ethics Committee and Governance and Privacy office, respectively (Mater Misericordiae Ltd Human Research Ethics Committee, HREC/MML/61799). We analysed preterm birth rates during the strictest period of lockdown (30 March-1 May; 'late'). To examine effects of earlier behavioural and mitigation measures,[10] we also analysed an equal 33-day period commencing two weeks earlier (16 March-17 April; 'early'). Each period was compared with the exact same calendar period for seven years (2013–2019) preceding the COVID-19 pandemic. We assessed stillbirth rates during the entire study period (16 March-1 May).

Study design and participants

Deidentified obstetric and neonatal data were extracted from the hospital's electronic healthcare records database. Women with singleton pregnancies who birthed between 16 March to 1 May in years 2013–2020 were included in the main analyses. Preterm births were categorised as follows: 23 + 0–27 + 6 weeks (extremely preterm); 28 + 0–31 + 6 weeks (very preterm); and 32 + 0–36 + 6 weeks (moderate/late preterm) and only livebirths were included. The comparison group was live infants born at term (≥37 weeks gestation). Preterm birth rates were also analysed according to birth onset: planned (caesarean section or induction of labour) or spontaneous. Fourteen-day rolling averages (seven days prior to six days after) were calculated for the percentage of preterm births from January to June each year, to visually highlight trends. To eliminate effects of whole-year shifts in preterm birth prevalence, rolling averages were also presented as a percentage change from the average preterm birth for that year. Stillbirths at all gestational ages were included in this study.

In supplementary analyses, to capture the period of easing restrictions/post-lockdown (26 April to 9 May, 2020), preterm singleton livebirth rates were analysed according to birth onset: planned (caesarean section or induction of labour) or spontaneous. Comparisons to same timeframe of the preceding seven years (2013–2019) was undertaken. For this post-lockdown period, perinatal outcomes were determined by comparing rates of stillbirth, and admission to the neonatal intensive care unit (NICU) or special care nursery (SCN) and Apgar score <7 at five minutes for all livebirths.

Statistical analyses

Logistic regressions were performed for each restriction period to compare the probability of preterm vs full-term births in 2020 compared with consolidated 2013–2019 data. This was also performed for planned and spontaneous births separately. Multinomial logistic regressions were performed to assess the odds of being born in each preterm category vs the reference full-term category in 2020 compared with consolidated 2013–2019 data. We then performed confirmatory analyses, comparing the odds of preterm birth in each preceding year with 2020 set as the reference year using logistic regressions. Covariates in the adjusted models were key contributors to preterm birth, including maternal age, body mass index, ethnicity, parity, socioeconomic status, and history of or current asthma, diabetes mellitus, and/or hypertensive disorder based on signal differences ($P \leq 0.25$) in the distribution of cases between years by analysis of variance (ANOVA) (scale) or χ^2 testing (categorical). Socioeconomic status was represented by tertiles of the Socioeconomic Indexes for Areas (SEIFA, 2016) index of relative socioeconomic advantage and disadvantage scores for the maternal postcode of residence (lower, middle, upper). Maternal smoking status around the time of conception and/or the first trimester of pregnancy was not included in any of the adjusted models as these did not differ between the years. Information pertaining to alcohol consumption around the time of conception and/or the first trimester of pregnancy was also not included in any of the adjusted models as data were available for only 50% of the population each year. The prevalence of stillbirths was compared between the years using χ^2 testing.

For post-lockdown neonatal health variables, the odds of admission to the NICU or SCN and Apgar score <7 at five minutes for all singleton livebirths in each preceding year were compared with 2020 using logistic regression. Maternal age, parity, socio-economic status, diabetes mellitus and hypertensive disorder were included in the adjusted model based on signal differences ($P \leq 0.25$) in the distribution of cases between years by ANOVA (scale) or χ^2 testing (categorical).

RESULTS

In the last eight years from mid-January to mid-June, the proportion of all preterm births was at its lowest level at the end of March to mid-April, 2020, which coincides with the implementation of COVID-19 restrictions (Fig. 1A, *N* = 2973 preterm infants/35 028 full-term infants from Jan 8–Jun 21 2013–2020). This was primarily

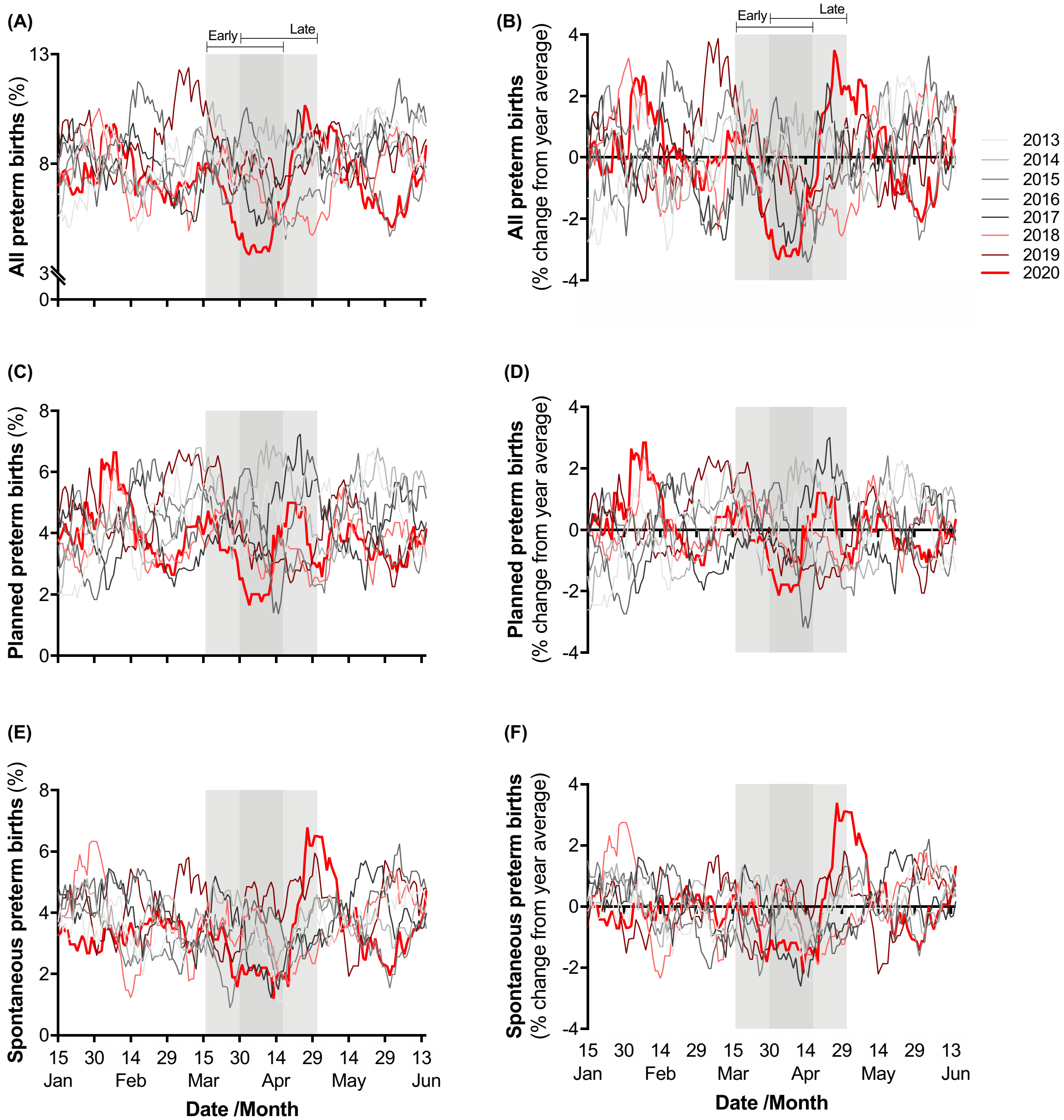

FIGURE 1 Proportion of preterm singleton livebirths. (A, B) All preterm births, (C, D) planned preterm births (birth onset by caesarean section or induction), and (E, F) spontaneous preterm births presented as absolute proportion (left panel) and percentage change from January to June year average (right panel). Rolling 14-day average from mid-January to mid-June in years 2013–2020. Plotted dates correspond to average from seven days prior to six days after. Shading represents the two study periods, with dark grey indicating the overlapping study period. Rolling averages calculated from *n* = 2973 preterm infants/35 028 full-term infants born on Jan 8–Jun 21, 2013–2020.

attributed to a reduction in planned, and not spontaneous, preterm births (Fig. 1C,E). When adjusted for inter-year variability, preterm birth prevalence in 2020 remained low at the end of March to mid-April compared with all other years, also due to a decline in planned preterm births (Fig. 1b,d,f). There was a two-week spike in spontaneous preterm births from the end of April to early May, 2020 (Fig. 1E,F).

Table 1 shows maternal characteristics of all singleton livebirths between March 16 and May 1 in years 2013–2020. Subsequent analyses for the 'early' period (March 16–April 17) included 6955 births (510 preterm; 48 extremely preterm, 69 very preterm, 393 moderate/late preterm) and for the 'late' restriction period (March 30–May 1), 6953 births were included (501 preterm; 42 extremely preterm, 64 very preterm, 395 moderate/late preterm).

During the 'early' period in 2020, 49 per 1000 singleton livebirths were preterm vs an average of 77 per 1000 singleton livebirths during the same calendar weeks of the previous seven years (adjusted odds ratio (aOR) 0.62, 95% CI 0.43–0.88, $P < 0.01$; Table 2). This was attributed to a decline in moderate/late preterm births (aOR 0.53, 95% CI 0.35–0.80, $P < 0.01$; Table 2). To confirm that this was a consistent finding compared with each preceding year, 2020 was set as the reference year which showed that the adjusted odds of moderate/late preterm birth remained ~1.6–2.4-times higher in all preceding years (Table S1). There were no differences in extremely preterm or very preterm births between year 2020 and the preceding seven years (Table 2, Table S1).

During the 'late' period in 2020, the prevalence of preterm birth was 59 per 1000 singleton births vs an average of 74 during the same calendar weeks of the previous seven years (aOR 0.74, 95% CI 0.54–1.03, $P = 0.07$; Table 2). This was attributed to a trending reduction in moderate/late preterm births in the adjusted model (aOR 0.73, 95% CI 0.51–1.05, $P = 0.09$; Table 2, Table S1).

We then separated the analyses by type of birth onset. A reduction in planned, but not spontaneous, moderate/late preterm births was seen during the 'early' period compared with consolidated 2013–2019 data (aOR 0.39, 95% CI 0.22–0.71, $P < 0.01$; Table 3). When 2020 was set as the reference year, the adjusted odds of planned moderate/late preterm birth during the 'early' period was 2.2–3.3-times greater in all preceding years (Table S2). The reduction in planned moderate/late preterm birth was less pronounced during the 'late' period (aOR 0.61, 95% CI 0.38–0.99, $P < 0.05$; Table 3, Table S2).

Between March 16 to May 1, the rate of stillbirths for all singleton pregnancies (19–43 weeks gestation) did not differ between 2013 to 2020 inclusive (χ^2 (7, N = 10 044) = 4.680, $P = 0.70$; year: N (%): 2013: 8 (0.7); 2014: 5 (0.4); 2015: 4 (0.3); 2016: 8 (0.6); 2017: 8 (0.6); 2018: 4 (0.3); 2019: 4 (0.3); 2020: 6 (0.5)).

To capture the two-week post-lockdown spike in spontaneous preterm births in 2020 (26 April to 9 May), logistic regression was performed. Compared with 2020, the odds of preterm vs full-term spontaneous birth was lower only in 2014 (aOR 0.50, 95% CI 0.24–1.07, $P = 0.07$) and 2017 (aOR 0.49, 95% CI 0.22–1.10, $P = 0.08$, Table S3). Admittance to the NICU/SCN, and the proportion of infants with an Apgar score <7 at five minutes was not increased during this, largely non-significant, spike in preterm births compared with previous years (Table S3). Furthermore, no singleton neonatal deaths were reported between 26 April to 9 May, 2020 and singleton stillbirth rates did not differ between 2013 and 2020 inclusive (χ^2 (7, N = 3055) = 2.758, $P = 0.91$; year: N (%): 2013: 4 (1.1); 2014: 2 (0.5); 2015: 4 (1.0); 2016: 3 (0.8); 2017: 3 (0.8); 2018: 2 (0.5); 2019: 3 (0.8); 2020: 1 (0.3)).

DISCUSSION

In this study, at a tertiary perinatal hospital in Queensland, Australia, a significant reduction in preterm births was observed following the implementation of measures to contain the spread of COVID-19. The reduction was driven primarily by a decline in moderate/late preterm infants, and the greatest impact was seen during the earliest period of restrictions. Furthermore, this reduction was attributed to planned, but not spontaneous, preterm births in singleton pregnancies. Our data contribute to the growing evidence from other countries[5–9] and, together, may reveal novel factors linked to preterm birth.

During early restrictions, planned births for moderate/late preterm infants reduced by more than half when compared with the preceding seven years. Self-isolation may have resulted in reduced work- and social-related stress, improved sleep quality and/or diet, with an overall improvement to pregnancy health, such as controlled blood pressure, and reduced requirement for a planned preterm birth. Other reasons may include more telehealth antenatal appointments and a possible reduction in care-seeking behaviour by pregnant women. Furthermore, given the uncertainty of the situation at the time, and the close locality of the maternity hospital to the general adult hospital, it is possible that women avoided seeking care for antenatal concerns that would normally be grounds for a planned preterm birth.

Almost immediately following the nadir in planned preterm births, there was a spike in spontaneous preterm births from late April to early May, although this was largely not significant when compared with previous years. While it is possible that the same women who did not undergo a medically indicated planned preterm birth in the preceding two weeks subsequently went into spontaneous preterm labour, this is likely to be a chance finding. Further analyses of preterm birth rates by gestational weeks using a larger dataset may support this observation. During this time period, no neonatal deaths were reported, and NICU/SCN admissions and Apgar scores <7 at five minutes were not increased compared with previous years.

The earliest period of restrictions, before the government-imposed hard lockdown, had the greatest influence on reducing planned preterm birth rates. In Australia, there was a remarkable spike in the 'panic index' in early March.[10] This did not coincide with any major restrictions to movement or travel, or local COVID-19

TABLE 1 Maternal characteristics of singleton livebirths between March 16–May 1 by year

	2013	2014	2015	2016	2017	2018	2019	2020
Total *N*	1194	1262	1269	1254	1233	1244	1299	1231
Age, median, IQR, (*n*)†	31.8, 6.6 (1194)	31.9, 6.7 (1262)	31.9, 6.8 (1269)	32.3, 6.9 (1254)	32.0, 6.6 (1233)	32.4, 6.5 (1244)	31.9, 6.8 (1299)	32.7, 6.9 (1231)
BMI, median, IQR, (*n*)†	23.1, 6.3 (1186)	22.9, 6.3 (1257)	22.9, 6.0 (1258)	22.7, 5.5 (1247)	22.7, 5.6 (1230)	22.9, 6.3 (1227)	22.8, 5.5 (1283)	23.3, 6.2 (1215)
Ethnicity, %, (*n*)†								
Caucasian	69.0 (822/1192)	64.5 (813/1261)	64.8 (821/1266)	60.4 (756/1252)	61.2 (754/1233)	60.2 (746/1240)	61.3 (792/1291)	59.8 (735/1230)
Aboriginal and Torres Strait Islander	2.1 (25/1192)	1.9 (24/1261)	2.1 (27/1266)	2.6 (32/1252)	2.5 (31/1233)	2.3 (29/1240)	2.0 (26/1291)	2.8 (34/1230)
Asian	12.4 (148/1192)	15.1 (190/1261)	13.0 (164/1266)	15.4 (193/1252)	14.9 (184/1233)	13.8 (171/1240)	13.6 (175/1291)	13.5 (166/1230)
South Asian	6.1 (73/1192)	7.1 (89/1261)	8.5 (108/1266)	9.3 (117/1252)	8.5 (105/1233)	8.9 (110/1240)	9.7 (125/1291)	10.5 (129/1230)
Other	10.4 (124/1192)	11.5 (145/1261)	11.5 (146/1266)	12.3 (154/1252)	12.9 (159/1233)	14.8 (184/1240)	13.4 (173/1291)	13.5 (166/1230)
Parity, %, (*n*)								
0	26.5 (316)	39.3 (495)	49.9 (632)	50.2 (628)	66.5 (820)	68.4 (845)	72.8 (942)	74.1 (903)
1	48.4 (578)	40.8 (514)	31.1 (394)	31.2 (390)	20.6 (254)	19.2 (237)	15.9 (206)	17.5 (213)
2	17.4 (208)	11.5 (145)	11.7 (148)	11.1 (139)	6.9 (85)	6.4 (79)	6.9 (89)	4.8 (59)
3+	7.6 (91)	8.5 (107)	7.3 (93)	7.6 (95)	6.0 (74)	6.1 (75)	4.4 (57)	3.6 (44)
Residence socioeconomic status, %, (*n*)								
Low	14.8 (177)	13.3 (167)	14.7 (186)	15.1 (189)	14.0 (172)	16.3 (202)	14.7 (191)	13.0 (160)
Middle	12.6 (150)	15.6 (196)	18.4 (233)	17.9 (224)	16.7 (206)	17.1 (212)	16.0 (207)	17.5 (216)
Upper	72.6 (865)	71.2 (897)	66.9 (847)	67.0 (840)	69.3 (852)	66.6 (827)	69.3 (899)	69.5 (855)
History or current chronic disease, %, (*n*)†								
Asthma	18.9 (225/1191)	17.6 (222/1261)	17.2 (218/1267)	17.4 (218/1253)	17.0 (209/1229)	16.2 (201/1243)	15.6 (203/1298)	14.1 (174/1231)
Diabetes	6.7 (78/1161)	7.3 (90/1228)	8.4 (106/1264)	8.2 (102/1239)	8.9 (107/1209)	9.7 (119/1222)	8.0 (103/1281)	11.8 (143/1207)
Hypertensive disorders	7.8 (93/1194)	6.5 (82/1262)	5.9 (75/1269)	5.5 (69/1254)	5.7 (70/1233)	4.6 (57/1244)	4.7 (61/1299)	3.9 (48/1231)
Smoking, %, (*n*)†,‡	12.8 (152/1187)	12.0 (142/1188)	12.1 (145/1199)	11.6 (143/1231)	11.9 (145/1217)	10.9 (133/1215)	12.9 (164/1268)	11.1 (134/1207)
Alcohol consumption, %, (*n*)†,‡	38.4 (242/631)	31.9 (200/626)	35.5 (221/622)	29.2 (177/607)	30.6 (185/604)	44.3 (273/616)	41.4 (281/678)	35.2 (225/639)
Medically indicated birth onset, %, (*n*)								
Caesarean section	27.5 (328)	23.9 (301)	22.5 (286)	22.2 (278)	19.4 (239)	18.9 (235)	20.2 (262)	20.8 (256)
Induction of labour	28.4 (339)	29.4 (371)	32.5 (412)	33.8 (424)	37.0 (456)	37.8 (470)	37.4 (486)	41.1 (506)

BMI, body mass index; IQR, interquartile range
†Some missing data for age, BMI, ethnicity, chronic disease, smoking and alcohol consumption, with total *n* indicated in parentheses.
‡Smoking and alcohol consumption in early pregnancy.

TABLE 2 Distribution of singleton livebirths by gestational age category for each year, and odds of preterm singleton livebirths in year 2020 compared with consolidated 2013–2019 data

	2013	2014	2015	2016	2017	2018	2019	2020	2013–2019	2020	2020 vs consolidated 2013–2019	
	N (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)	*N* (%)	Per 1000 (SD)	Per 1000	uOR (95% CI)	aOR (95% CI)
Early restriction period 16 March – 17 April												
Total preterm	64 (7.7)	80 (9.1)	59 (6.7)	68 (7.8)	61 (7.0)	66 (7.6)	71 (7.8)	41 (4.9)	76.67 (0.007)	48.93	0.62 (0.45–0.86)*	0.62 (0.43–0.88)*
Full-term	765 (92.3)	802 (90.9)	818 (93.3)	807 (92.2)	807 (93.0)	806 (92.4)	843 (92.2)	797 (95.1)	923.33 (0.007)	951.07	–	–
Extremely preterm	6 (0.7)	8 (0.9)	5 (0.6)	5 (0.6)	4 (0.5)	5 (0.6)	8 (0.9)	7 (0.8)	6.70 (0.002)	8.35	1.21 (0.54–2.71)	1.70 (0.69–4.20)
Very preterm	9 (1.1)	9 (1.0)	10 (1.1)	8 (0.9)	11 (1.3)	8 (0.9)	9 (1.0)	5 (0.6)	10.46 (0.001)	5.97	0.55 (0.22–1.38)	0.62 (0.22–1.75)
Mod/late preterm	49 (5.9)	63 (7.1)	44 (5.0)	55 (6.3)	46 (5.3)	53 (6.1)	54 (5.9)	29 (3.5)	59.51 (0.007)	34.61	0.57 (0.38–0.83)*	0.53 (0.35–0.80)*
Total births	829 (100)	882 (100)	877 (100)	875 (100)	868 (100)	872 (100)	914 (100)	838 (100)	1000	1000		
Late restriction period 30 March – 1 May												
Total preterm	61 (7.5)	79 (8.9)	60 (6.8)	68 (7.8)	61 (7.1)	51 (6.1)	68 (7.5)	53 (5.9)	73.93 (0.009)	59.35	0.79 (0.59–1.06)	0.74 (0.54–1.03)^
Full-term	751 (92.5)	805 (91.1)	826 (93.2)	806 (92.2)	803 (92.9)	788 (93.9)	833 (92.5)	840 (94.1)	926.07 (0.009)	940.65	–	–
Extremely preterm	6 (0.7)	4 (0.5)	3 (0.3)	6 (0.7)	6 (0.7)	5 (0.6)	7 (0.8)	5 (0.6)	6.11 (0.002)	5.60	0.90 (0.35–2.30)	1.02 (0.35–2.94)
Very preterm	8 (1.0)	11 (1.2)	8 (0.9)	7 (0.8)	7 (0.8)	7 (0.8)	10 (1.1)	6 (0.7)	9.57 (0.002)	6.72	0.69 (0.30–1.61)	0.63 (0.22–1.77)
Mod/late preterm	47 (5.8)	64 (7.2)	49 (5.5)	55 (6.3)	48 (5.6)	39 (4.6)	51 (5.7)	42 (4.7)	58.25 (0.008)	47.03	0.80 (0.57–1.10)	0.73 (0.51–1.05)^
Total births	812 (100)	884 (100)	886 (100)	874 (100)	864 (100)	839 (100)	901 (100)	839 (100)	1000	1000		

aOR, adjusted odds ratio for maternal age, body mass index, ethnicity, parity, socioeconomic status by residence, and history or current asthma, diabetes, and/or hypertensive disorder; uOR, unadjusted odds ratio.
*$P < 0.01$.
^$P = 0.073$–0.087.

TABLE 3 Odds of preterm singleton livebirths by birth onset (planned or spontaneous) in year 2020 compared with consolidated 2013–2019 data

	Planned births				Spontaneous births			
	2013–2019	2020	2020 vs consolidated 2013–2019		2013–2019	2020	2020 vs consolidated 2013–2019	
	Per 1000 (SD)	Per 1000	uOR (95% CI)	aOR (95% CI)	Per 1000 (SD)	Per 1000	uOR (95% CI)	aOR (95% CI)
Early restriction period 16 March – 17 April								
Total preterm	80.37 (0.011)	44.06	0.53 (0.34–0.82)*	0.50 (0.31–0.83)*	72.06 (0.012)	57.14	0.78 (0.48–1.28)	0.80 (0.48–1.36)
Full-term	919.63 (0.011)	955.94	–	–	927.94 (0.012)	942.86	–	–
Extremely preterm	5.30 (0.003)	7.66	1.39 (0.47–4.13)	2.31 (0.61–8.66)	8.46 (0.003)	9.52	1.11 (0.33–3.71)	1.33 (0.37–4.75)
Very preterm	11.48 (0.002)	7.66	0.64 (0.23–1.81)	0.72 (0.21–2.44)	9.19 (0.003)	3.18	0.34 (0.05–2.52)	0.38 (0.05–2.98)
Mod/late preterm	63.59 (0.009)	28.74	0.44 (0.26–0.74)*	0.39 (0.22–0.71)*	54.41 (0.013)	44.44	0.80 (0.46–1.41)	0.77 (0.43–1.40)
Late restriction period 30 March – 1 May								
Total preterm	75.35 (0.018)	51.60	0.67 (0.45–0.99)*	0.66 (0.42–1.01)^	72.15 (0.016)	72.73	1.01 (0.65–1.57)	0.93 (0.57–1.51)
Full-term	924.65 (0.034)	948.40	–	–	927.85 (0.016)	927.27	–	–
Extremely preterm	3.25 (0.002)	5.34	1.60 (0.45–5.76)	1.48 (0.31–7.10)	9.72 (0.005)	6.06	0.62 (0.15–2.64)	0.83 (0.19–3.60)
Very preterm	9.75 (0.024)	5.34	0.53 (0.16–1.75)	0.70 (0.21–2.40)	9.35 (0.003)	9.09	0.97 (0.29–3.24)	0.49 (0.06–3.73)
Mod/late preterm	62.35 (0.019)	40.92	0.64 (0.41–0.99)*	0.61 (0.38–0.99)*	53.08 (0.015)	57.58	1.09 (0.66–1.78)	0.99 (0.58–1.68)

aOR, adjusted odds ratio for maternal age, body mass index, ethnicity, parity, socioeconomic status by residence, and history or current asthma, diabetes, and/or hypertensive disorder; uOR, unadjusted odds ratio.
$^{*}P < 0.01$.
$^{\wedge}P = 0.057$.

cases, but was likely related to observations by the general population of the international impacts of COVID-19. At this time, hand sanitisers and antibacterial handwashes sold out in most parts of the country, highlighting the magnitude of behaviour change. This timing is somewhat consistent with a large nationwide study from the Netherlands, which reported reductions in moderate/late preterm births in the 2–4-month period following initial mitigation measures, but not when stricter measures were introduced 1–2 weeks later, albeit there was no separation by planned and spontaneous preterm births.[7]

We did not see a persistent level of reduction in moderate/late planned preterm births later in the pandemic, following the implementation of more formal lockdown measures. Given that COVID-19 cases did not rise as initially expected in Australia, it is possible that attending hospital for antenatal concerns in these later weeks was no longer avoided. Alternatively, unintended consequences of prolonged isolation, such as reduced physical activity and mental health concerns, may have counterbalanced the benefits from other, early behavioural changes that impact on pregnancy health. A study from Canada recruited pregnant and new mothers between mid-April and early May and found that self-reported measures of physical activity were reduced, and levels of depression and anxiety were increased compared with pre-pandemic levels.[11] During the hard lockdown in Australia specifically, mental health concerns including depression and anxiety were widespread in the general population.[12]

A nationwide study in Denmark found no effect on moderate/late or very preterm births during the strictest month of lockdown compared with the same calendar period in the previous five years.[6] However, a significant reduction in extremely preterm births was observed. Similarly, in a designated area of Ireland, the proportion of extremely and very low birthweight infants was unusually low in the first four months of 2020 compared with the same period in the preceding 19 years.[8] It is difficult to ascertain why the Danish and Irish observed reductions in the earliest and smallest infants[6,8] while we, the Dutch,[7] and Italians[5] observed reductions in moderate/late preterm births only. Furthermore, there have been reports of adverse neonatal outcomes during lockdown, including a 1.5-fold increase in stillbirth and three-fold increase in neonatal mortality in Nepal,[4] a six-fold increase in stillbirth in a London hospital,[3] and a 2.6-fold increase in stillbirth in a large region in Italy.[5] Indeed, a recent meta-analysis reported that while preterm birth rates declined in high-income countries (12 studies), stillbirth (12 studies) and maternal death (two studies) significantly increased in low- and middle-income countries.[13] The burden of rising COVID-19 cases, implementation of formal restriction measures, and governmental and population responses have varied across the globe,[10,14] which may underlie some of the observed differences.

We included all livebirths ≥23 completed weeks of gestation, as active resuscitation and support is usually offered from this gestation depending on parental wishes. While our statistical analyses also included some babies who later died in hospital during March 16-May 1, 2013–2020 (*n* = 21/9986 singleton livebirths), we feel this is a better representation of the birthing population, especially of those born preterm. Furthermore, while the percentage of nulliparity steadily increased over the years, this is not likely to have contributed to the increased preterm birth rates in 2020 given that parity was included in the adjusted models and a decline in preterm birth was seen in 2020 vs 2019 alone, despite similar rates of nulliparity (72.8 vs 74.1%). Our study has some limitations. This was a retrospective data collection approach using a hospital database that had some missing data. While there were no differences in extremely and very preterm birth rates, stillbirth rates, and neonatal deaths over the study period, the overall numbers are relatively small and the results should be interpreted with caution. Furthermore, it is possible that we received fewer referrals from other local perinatal centres during the restriction period, due to patient avoidance of the tertiary setting.

Preterm birth is the leading cause of neonatal death globally, and those who survive are at greater risk of cognitive, behavioural, motor, and respiratory impairments.[15–18] The preterm birth rate is increasing in most parts of the world, mainly attributed to increases in planned preterm births.[19–21] We show that our early response to the COVID-19 pandemic was associated with a reduction in planned moderate/late preterm births. This aligns with studies from other countries,[5–9] albeit differences are seen with respect to which gestational age category was most positively affected and we are the first to differentiate between planned and spontaneous preterm births. A global effort is now exploring the links between COVID-19 restrictions, preterm births, regional variation, and temporal trends (https://www.ipopstudy.com/).

ACKNOWLEDGEMENTS

The authors wish to acknowledge the contributions of Yanlin Liu for data extraction through Mater Data and Analytics, and Nicholas Matigian for statistical support through the Research and Statistical Support Service, Faculty of Medicine, provided by QCIF Facility for Advanced Bioinformatics (QFAB), The University of Queensland. LAG was supported by a UQ Amplify Fellowship, and KMM and VLC were supported by Senior Research Fellowships from the National Health and Medical Research Council (Australia).

REFERENCES

1. Guo Y-R, Cao Q-D, Hong Z-S, *et al*. The origin, transmission and clinical therapies on coronavirus disease 2019 (COVID-19) outbreak - an update on the status. *Mil Med Res* 2020; **7**(1): 11.
2. Queensland Health. Chief Health Officer public health directions: Queensland Government. 2020. Available from: https://www.health.qld.gov.au/system-governance/legislation/cho-public-health-directions-under-expanded-public-health-act-powers/revoked. Accessed October 30, 2020.
3. Khalil A, von Dadelszen P, Draycott T, *et al*. Change in the incidence of stillbirth and preterm delivery during the COVID-19 pandemic. *JAMA* 2020; **324**(7): 705.

4. Kc A, Gurung R, Kinney MV, *et al*. Effect of the COVID-19 pandemic response on intrapartum care, stillbirth, and neonatal mortality outcomes in Nepal: a prospective observational study. *Lancet Glob Health* 2020; **8**(10): e1273–e1281.
5. De Curtis M, Villani L, Polo A. Increase of stillbirth and decrease of late preterm infants during the COVID-19 pandemic lockdown. *Arch Dis Child Fetal Neonatal Ed* 2021; **106**(4): 456.
6. Hedermann G, Hedley PL, Bækvad-Hansen M, *et al*. Danish premature birth rates during the COVID-19 lockdown. *Arch Dis Child Fetal Neonatal Ed* 2021; **106**(1): 93–95.
7. Been JV, Burgos Ochoa L, Bertens LCM, *et al*. Impact of COVID-19 mitigation measures on the incidence of preterm birth: a national quasi-experimental study. *Lancet Public Health* 2020; **5**(11): e604–e611.
8. Philip RK, Purtill H, Reidy E, *et al*. Unprecedented reduction in births of very low birthweight (VLBW) and extremely low birthweight (ELBW) infants during the COVID-19 lockdown in Ireland: a 'natural experiment' allowing analysis of data from the prior two decades. *BMJ Glob Health* 2020; **5**(9): e003075.
9. Meyer R, Bart Y, Tsur A, *et al*. A marked decrease in preterm deliveries during the coronavirus disease 2019 pandemic. *Am J Obstet Gynecol* 2020; **224**(2): 234–237.
10. Keane M, Neal T. Consumer panic in the COVID-19 pandemic. *J Econom* 2020; **220**(1): 86–105.
11. Davenport MH, Meyer S, Meah VL, *et al*. Moms Are Not OK: COVID-19 and maternal mental health. *Front Glob Women's Health* 2020. https://doi.org/10.3389/fgwh.2020.00001
12. Fisher JR, Tran TD, Hammarberg K, *et al*. Mental health of people in Australia in the first month of COVID-19 restrictions: a national survey. *Med J Aust* 2020; **213**(10): 458–464.
13. Chmielewska B, Barratt I, Townsend R, *et al*. Effects of the COVID-19 pandemic on maternal and perinatal outcomes: a systematic review and meta-analysis . *Lancet Glob Health.* 2021; **9**(6): e759.
14. COVID-19 Law Lab; 2020. Available from: https://covidlawlab.org/. Accessed October 30, 2020.
15. United Nations Inter-agency Group for Child Mortality Estimation (UNIGME). Levels & Trends in Child Mortality: Report 2019, Estimates developed by United Nations Inter-agency Group for Child Mortality Estimation. New York; 2019.
16. Caravale B, Tozzi C, Albino G, Vicari S. Cognitive development in low risk preterm infants at 3–4 years of life. *Arch Dis Child Fetal Neonatal Ed* 2005; **90**(6): F474–F479.
17. Näsänen-Gilmore P, Sipola-Leppänen M, Tikanmäki M, *et al*. Lung function in adults born preterm. *PLoS One* 2018; **13**(10): e0205979.
18. Moreira RS, Magalhaes LC, Alves CR. Effect of preterm birth on motor development, behavior, and school performance of school-age children: a systematic review. *J Pediatr* 2014; **90**(2): 119–134.
19. Australian Institute of Health and Welfare 2020. *Australia's mothers and babies 2018: in brief*. Canberra: AIHW, 2018.
20. Chawanpaiboon S, Vogel JP, Moller A-B, *et al*. Global, regional, and national estimates of levels of preterm birth in 2014: a systematic review and modelling analysis. *Lancet Glob Health* 2019; **7**(1): e37–e46.
21. Goldenberg RL, Culhane JF, Iams JD, Romero R. Epidemiology and causes of preterm birth. *Lancet* 2008; **371**(9606): 75–84.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1. Odds of preterm singleton livebirths in each year compared with year 2020.

Table S2. Odds of preterm singleton livebirths by birth onset (planned or spontaneous) in each year compared with year 2020.

Table S3. Odds of preterm singleton livebirths by birth onset (planned or spontaneous), all singleton admissions to neonatal intensive care unit / special care nursery (NICU/SCN), and all singleton Apgar scores of <7 at five minutes in each year compared with year 2020 easing restrictions/post-lockdown period.