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Trends in adverse pregnancy outcomes in Louisiana, 2017 to 2022

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Natural disasters can lead to more adverse pregnancy outcomes (APO). It is unclear if the extended COVID-19 pandemic has impacted APOs and pre-existing conditions among perinatal populations with increased risk of severe maternal morbidity and mortality.

A retrospective chart review was conducted of hospital records and birth certificates in the largest birth hospital in Louisiana from 2017 to 2022. Amongst 27,877 births (50.9% White, 38.3% Black, 28.9 ± 5.6 years), gestational diabetes (GDM) was lowest in pre-pandemic conceptions (11.0%, June 2017-May 2019) and rose to 16.4% early pandemic (October 2019-February 2020) but leveled off at 12.2% in peak (March 2020-February 2021) and late pandemic (March 2021-September 2021). Individuals who conceived in early and peak pandemic were 47% (95% CI 33, 63) and 11% (95% CI 2, 20) more likely to develop GDM respectively, compared to pre-pandemic conceptions. Individuals who delivered during early (aRR: 1.54, 95% CI 1.33–1.78), peak (aRR: 1.48, 95% CI 1.32–1.65), and late (aRR: 1.62, 95% CI 1.41, 1.85) pandemic were more likely to develop preeclampsia and HELLP syndrome compared to pre-pandemic conceptions. Individuals were also 17% (95% CI 5, 32) more likely to enter pregnancy with chronic hypertension in peak pandemic compared to pre-pandemic. In paired analysis (*n* = 3390), individuals with a pandemic conception that occurred early pandemic had a higher risk of developing GDM compared to their pre-pandemic pregnancy (aOR 3.26, 95% CI 1.52, 6.97). Supporting birthing individuals amongst significant stressful events, especially in early gestation, is critical for preventing APOs and severe maternal morbidity and mortality.

Adverse exposures and experiences during pregnancy can negatively impact perinatal health,[1,2] and subsequent health of mothers and children.[3–5] Disaster research of pregnant individuals exposed to stressful events, such as hurricanes, earthquakes, and acts of terror, describes an association between severity of exposure and risk of adverse outcomes. Individuals with severe exposure to the disasters, such as the terrorist attack on the World Trade Center (September, 2001) and Quebec Ice Storm (January, 1998) experienced higher rates of preterm birth and low birthweight infants compared to less direct exposure.[6–8] Similarly, residents who experienced high stress (e.g., having a loved one die) during Hurricane Katrina (August 2005) were also at increased risk for delivering low birthweight infants.[9]

The COVID-19 pandemic is a contemporaneous stressful event that directly and indirectly impacted pregnant individuals. Both SARS-CoV-2 infection while pregnant as well as experiencing pregnancy during the COVID-19 pandemic (e.g., reduced access to prenatal care,[10] increased stress and isolation,[11] and time spent sedentary)[12] have adversely impacted perinatal health.[13] Early pandemic reports have focused on the impact of infection, demonstrating that SARS-CoV-2 infection in pregnancy increases risk for preterm birth, maternal intensive care unit admission, respiratory intubation, stillbirth, preeclampsia, and maternal death.[14–17] However, investigations of the pandemic's impact on adverse pregnancy outcomes (APOs) regardless of infection are less consistent. For example, reports of no change[18] and increases[15,17] in stillbirth rates were reported in the early pandemic. Early pandemic studies, namely examining the first year (2020–2021), also reported increased risks of gestational diabetes (GDM), maternal death, and depression among pregnant individuals during the pandemic compared to before March 2020.[15,17,19–23] Conversely, incidence of preterm birth, preeclampsia, and severe maternal morbidity did not change, and reviews report inconsistent findings.[17,24].

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Examination of APOs across later parts of the pandemic as well may better characterize the full impact of this disaster on APOs. This approach will improve upon past investigations that have focused solely on the first year of the pandemic, and primarily compared APOs before and during the pandemic.[19] Prenatal care and access returned to normal later in the pandemic,[25] but remained a stressful experience for many.[26] Individuals likely continued to face stress during their daily lives. Early pandemic lifestyle changes resulted in many gaining additional weight,[27,28] which contributes to development of chronic conditions (e.g., hypertension). It is hypothesized that pre-existing conditions related to lifestyle, e.g., type 2 diabetes and hypertension, have also risen in pregnant individuals in later pandemic. Determining these rates will have important implications for prenatal support and care in a post-pandemic world.

The aim of this work is to address the gap in understanding of trends in APOs across the pandemic years, particularly considering the likelihood that the stress exposure to the pandemic varied as vaccinations became available, healthcare accessibility returned, and social distancing protocols lessened. Herein, we analyzed patterns of APOs in annual increments during early, peak, and later pandemic compared to before the pandemic. We tested the hypothesis that APOs increased in early and peak pandemic compared to pre-pandemic (Aim 1). We also hypothesized that pre-existing conditions would increase in later pandemic compared to pre-pandemic and early pandemic (Aim 2). Further, we explored changes in APOs between individuals who had a pre-pandemic and pandemic pregnancy (Aim 3). We hypothesized that APOs would be higher in their pandemic pregnancy.

Methods

Study design

This retrospective examination utilized electronic health records data from women (ages 12–50 years) who delivered from a large women's specialty hospital in a metropolitan city of Louisiana between June 1, 2017 and July 31, 2022. This report follows guidelines for reporting observational studies (Supplementary Table 1). The first COVID-19 case in Louisiana was diagnosed March 13th, 2020,[29] thus pandemic-affected pregnancies were considered those conceived after this date. The larger cohort was assembled to detect an odds ratio of ≥ 0.91 when comparing above vs. recommended gestational weight gain (GWG) between pre-pandemic and pandemic pregnancies (80% power) for the study's primary research question.[27] We sought 6000 pre-pandemic and 12,000 pandemic deliveries ($\alpha = 0.05$) based on pre-pandemic estimates.[30] This study was granted waivers of informed consent and HIPAA authorization and determined to be exempt by Woman's Hospital Foundation Institutional Review Board (FWA: 0,005,699; IRB Registration: 00,003,774).

Hospital delivery record data were abstracted using recommended medical practices for abstracting medical records.[31] Data were compiled using Structured Query Language programming utilizing International Classification of Diseases 10th Revision diagnostic and procedure codes, admitting and discharge notes, and nurse and physician charting. Individual chart comparisons and examination for outliers were used to validate the dataset. Hospital delivery record data were matched, validated, and supplemented with the Louisiana Department of Health birth certificate data. There were no major changes in diagnostic procedures for adverse pregnancy outcomes within this hospital during the period.

Definition of study periods: COVID-19 pandemic

APOs were defined by estimated conception date to allow for comparable exposure timing as these outcomes were likely strongly affected by gestational age of exposure and seasonal patterning.[32] Month of conception was estimated based on delivery date and gestational age [days] at delivery. Four groups were compared: pre-pandemic (conceived > 10 months before onset of pandemic: June 1, 2017—May 1, 2019), early pandemic (conceived prior to pandemic onset, but part of pregnancy occurred during the pandemic: October 1, 2019—February 28, 2020), peak pandemic (pandemic conception with some pregnancy during peak: March 1, 2020—February 28, 2021), and late pandemic (conceived after social distancing restrictions were lifted: March 1, 2021—September 1, 2021). We excluded probable conception between May–October 2019 or prior to June 2017 due to varying lengths of gestation and pandemic exposure ($n = 2{,}433$).

Adverse pregnancy outcomes

APOs were documented within the delivery medical record, validated with the birth certificate data, and used binary metrics ("yes" or "no"). Diabetes status metrics included GDM and type 2 diabetes diagnosis prior to pregnancy. Hypertension was divided into chronic hypertension (pre-pregnancy hypertension) and pregnancy-induced hypertension. Pregnancy-induced hypertension was divided into either: 1) gestational hypertension ([GH], i.e., no chronic or preeclampsia), or 2) preeclampsia, super imposed preeclampsia, eclampsia, and Hemolysis, Elevated Liver enzymes and Low Platelets (herein: preeclampsia/HELLP). Preterm birth was defined as delivery before 37 weeks gestation.

Covariates

We explored the covariates that were predictors of these outcomes in previous investigations,[33–37] including pre-pregnancy body mass index (BMI), age, race/ethnicity, marital status, education, insurance type, employment status, smoking, alcohol use, and parity. Participant-reported pre-pregnancy weight (kg) and height (m) was used to calculate BMI using the standard equation (weight/height^2) and then classified as underweight: < 18.5 kg/m^2, normal weight:18.5–24.9 kg/m^2, overweight: 25–29.9 kg/m^2, obesity: ≥ 30 kg/m^2. Total GWG was calculated from routinely obtained self-reported weight measures reported at delivery (delivery weight – pre-pregnancy weight).

Statistical analysis

The final analytic sample for Aim 1 and 2 included 27,877 participants with complete data. There were 35,751 patients available who delivered or conceived within the time frame, but those who reported unknown or other race, or had missing data on pre-pregnancy BMI ($n = 2,589$, 7.2%) or smoking ($n = 168$, 0.5%) were excluded. Hospital delivery records for some patients (n = 2,294, 6.4%) were unable to be matched with birth records. Individuals missing delivery record data or who were unable to be matched with birth records were compared with those included within the analytical sample. Accordingly, the population with incomplete data on all outcomes, APOs, or covariates ($n = 3,011$, 8.4%), did not differ based on timing of delivery relative to the pandemic but were more likely to have less than a high school education, be unmarried, higher parity, or have obesity (p's < 0.05). The first recorded birth was used for each participant. For aim 3, 3,447 individuals who met the criteria overall but only 3,390 had complete data for all outcomes in both pregnancies.

For aim 1 and 2, APOs (GDM, GH, preeclampsia/HELLP, and preterm birth) and pre-existing conditions (pre-existing type 2 diabetes and chronic hypertension) amongst pandemic groups (pre-pandemic, early, peak, late) were compared using chi-square tests. Individual robust Poisson models were then used to examine the relative risk of APOs and chronic outcomes in pandemic groups relative to pre-pandemic pregnancies. These models were then adjusted for pre-pregnancy BMI, age, race/ethnicity, marital status, education, smoking status, total GWG, and parity.

For aim 3, we compared APOs amongst individuals with both a pre-pandemic and pandemic pregnancy. APOs considered were GDM, GH, preeclampsia and HELLP syndrome, and preterm birth. Pre-existing conditions were not considered in this aim since individuals who had them in the first pregnancy would qualify in the second pregnancy. Preeclampsia/HELLP were reduced to preeclampsia due to small numbers of other disorders. Kappa statistics and chi-square tests were used to compared agreement between diagnosis during pre-pandemic and pandemic pregnancies. Pandemic periods from aim 1 were used as a predictor in conditional logistic regression models. Adjusted models were conducted with time-varying covariates of age, parity, and pre-pregnancy BMI. All analyses were conducted in SAS 9.4 (Cary, N.C.) and significance was set at $p < 0.05$.

Results

Sample description

As shown in Table 1, there were 25,444 deliveries with mean age 28.9 ± 5.6 years, the majority were either White (50.9%) or Black (38.3%), and had normal weight (38.4%) or obesity (33.0%). There were small shifts in many categories across periods, including pre-pregnancy BMI category, age, race/ethnicity, marital status, education, insurance, smoking, alcohol use, and parity. Individuals who delivered late pandemic were slightly older, more likely to be employed, have higher education, private insurance, and be nulliparous than pre-pandemic pregnancies ($p < 0.01$). Slightly more individuals who delivered later pandemic were Hispanic (12.9%) compared to pre-pandemic (8.7%). Current and former smoking, and alcohol use fell in the late pandemic compared to pre-pandemic pregnancies ($p < 0.01$).

Adverse pregnancy outcomes by pandemic periods

GDM, chronic hypertension, GH, and preeclampsia/HELLP prevalence varied across pandemic periods (Table 2). GDM was lowest pre-pandemic (11.0%) and rose to 16.4% early pandemic but leveled off at 12.2% in the peak and late pandemic ($p < 0.001$). Chronic hypertension was highest during peak pandemic (6.9%) compared to pre-pandemic (5.6%, $p = 0.01$). GH was highest late pandemic (13.3%) and lowest pre-pandemic (11.3%, $p < 0.01$). Preeclampsia/HELLP had a steady increase from pre-pandemic (5.3%) to late pandemic (9.3%, $p < 0.01$). There were no changes in pre-existing type 2 diabetes or preterm birth across periods ($p > 0.05$).

As shown in Table 3, there was an effect of time for GDM, chronic hypertension, and preeclampsia/HELLP (p's < 0.05). Individuals who conceived in early and peak pandemic were 47% (95% CI: 33, 63) and 11% (95% CI: 2, 20), respectively, more likely to develop GDM compared to pre-pandemic conceptions after adjustment for covariates ($p < 0.05$). Individuals were also 17% (95% CI: 5, 32) more likely to enter pregnancy with chronic hypertension in peak pandemic compared to pre-pandemic pregnancies. For preeclampsia/HELLP, individuals who delivered during early (aRR: 1.54, 95% CI: 1.33–1.78), peak (aRR: 1.48, 95% CI: 1.32–1.65), and late (aRR: 1.62, 95% CI: 1.41, 1.85) pandemic were more likely to develop preeclampsia/HELLP compared to pre-pandemic pregnancies. There were no associations between pandemic period and GH after adjustment.

Paired inter-pregnancy analyses

In paired analysis ($n = 3,390$), GDM and preeclampsia were more likely in the pandemic pregnancy if the complication had occurred in the pre-pandemic pregnancy ($p < 0.01$). This association was stronger for GDM (Kappa = 0.46), than preeclampsia (Kappa = 0.12). There was no strong recurrence risk for GH or preterm birth (p for kappa > 0.05).

Gestational diabetes

More individuals had GDM in their pandemic pregnancy compared to pre-pandemic pregnancy (6.9%, $n = 235$) rather than the reverse (3.6%, $n = 123$), and some had GDM in both pregnancies (5.7%, $n = 193$). Those who developed GDM in their pandemic pregnancy only had a higher BMI (30.4) than those who only had GDM in their pre-pandemic pregnancy (28.9, $p = 0.06$, Supplementary Table 2).

Individuals were more likely to be diagnosed with GDM during their pandemic pregnancy compared to their pre-pandemic pregnancy (OR:1.91, 95% CI: 1.54, 2.38, Table 4), but this association was not significant after adjustment (aOR: 0.95, 95% CI: 0.48–1.87). Similarly, amongst all pandemic periods, individuals were more likely to have GDM in their pandemic pregnancy compared to their pre-pandemic pregnancy ($p < 0.05$ for all,

	Total ($n=25,444$)	Pre-Pandemic ($n=14,632$)	Early Pandemic ($n=2350$)	Peak Pandemic ($n=5640$)	Late Pandemic ($n=2822$)	
	June 2017- Sept 2021	June 2017-May 2019	October 2019-Feb 2020	March 2020-Feb 2021	Mar 2021- Sept 2021	*p*-value
	n (%)	n (%)	n (%)	n (%)	n (%)	
Pre-Pregnancy BMI Category						< .001
Underweight	744 (2.9)	441 (3.0)	75 (3.2)	148 (2.6)	80 (2.8)	
Normal	9776 (38.4)	5786 (39.5)	885 (37.7)	2108 (37.4)	997 (35.3)	
Overweight	6533 (25.7)	3716 (25.4)	619 (26.3)	1452 (25.7)	746 (26.4)	
Obesity	8391 (33.0)	4689 (32.1)	771 (32.8)	1932 (34.3)	999 (35.4)	
Maternal Age						< 0.001
< 18	276 (1.1)	130 (0.9)	21 (0.9)	91 (1.6)	34 (1.2)	
18–24	5958 (23.4)	3307 (22.6)	597 (25.4)	1400 (24.8)	654 (23.2)	
25–29	7887 (31.0)	4669 (31.9)	684 (29.1)	1655 (29.3)	879 (31.2)	
30–34	7069 (27.8)	4145 (28.3)	611 (26.0)	1530 (27.1)	783 (27.8)	
35–39	3487 (13.7)	1979 (13.5)	366 (15.6)	781 (13.9)	361 (12.8)	
≥ 40	767 (3.0)	402 (2.8)	71 (3.0)	183 (3.2)	111 (3.9)	
Race/Ethnicity						< .001
AN/PI	17 (0.1)	9 (0.1)	3 (0.1)	5 (0.1)	0 (0)	
Asian	531 (2.1)	325 (2.3)	40 (1.7)	109 (2.0)	57 (2.1)	
Black	9550 (38.3)	5457 (37.9)	897 (39.0)	2188 (39.9)	1008 (36.4)	
Hispanic	2168 (8.7)	1122 (7.8)	197 (8.6)	493 (9.0)	356 (12.9)	
White	12,693 (50.9)	7487 (52.0)	1165 (50.6)	2695 (49.1)	1346 (48.6)	
Maternal Education						< .001
< 12 years	2944 (11.6)	1739 (11.9)	252 (10.7)	629 (11.2)	324 (11.5)	
High School	6418 (25.2)	3458 (23.6)	630 (26.8)	1542 (27.4)	788 (27.9)	
Vocation School	1170 (4.6)	687 (4.7)	118 (5.0)	253 (4.5)	112 (4.0)	
Some College	4668 (18.4)	2715 (18.6)	454 (19.3)	1013 (18.0)	486 (17.2)	
College	7727 (30.4)	4578 (31.3)	674 (28.7)	1652 (29.3)	823 (29.2)	
Advanced Degree	2515 (9.9)	1455 (9.9)	222 (9.5)	549 (9.7)	289 (10.2)	
Maternal Insurance						< .001
Private	13,358 (52.6)	7872 (53.8)	1191 (50.9)	2831 (50.3)	1464 (52.0)	
Medicaid/self	12,054 (47.4)	6751 (46.2)	1151 (49.2)	2798 (49.7)	1354 (48.1)	
Parity						< .001
0	11,553 (45.4)	5824 (39.8)	1186 (50.5)	2984 (52.9)	1559 (55.2)	
1	7193 (28.3)	4623 (31.6)	585 (24.9)	1354 (24.0)	631 (22.4)	
2	4066 (16.0)	2530 (17.3)	356 (15.2)	800 (14.2)	380 (13.5)	
≥ 3	2632 (10.3)	1655 (11.3)	223 (9.5)	502 (8.9)	252 (8.9)	

Table 1. Descriptive statistics of the population giving birth before and during the COVID-19 pandemic by estimated conception date^ ^Assessed using chi-square analysis or Fisher exact test, Medicaid/self also includes prisoner; BMI = Body Mass Index; AN/PI = Alaska Native/Pacific Islander. Total N covers all conceptions between 6/1/17 and 3/12/22; sum of deliveries does not add to total due to conceptions occurring outside the listed time frames. Numbers may not sum to column total due to missing data on covariates.

Table 4). After adjustment, individuals with an early pandemic pregnancy had a higher risk of developing GDM compared to their pre-pandemic pregnancy (aOR 3.26, 95% CI: 1.52, 6.97).

Preeclampsia

A higher proportion of pregnancies had preeclampsia in the pre-pandemic period only (5.3%, $n=183$) than preeclampsia in the pandemic period only (3.4%, $n=118$). Those with preeclampsia only in their pandemic pregnancy were older, had a longer interpregnancy interval, and a higher pre-pregnancy BMI on average than those with preeclampsia only in their pre-pandemic pregnancy ($p<0.01$).

Overall, pandemic pregnancies (including both discrepant and non-discrepant) were less likely to be diagnosed with preeclampsia than pre-pandemic pregnancies (OR: 0.65, 95% CI: 0.51, 0.81). This association disappeared after adjustment (aOR 0.93, 95% CI: 0.50–1.74). Conception in the late pandemic period was associated with higher likelihood of preeclampsia (aOR 2.14, 95% CI: 1.01–4.50).

Discussion

This study examined patterns of APOs across a 5-year period, including 3-years of a global pandemic. Many APOs, including GDM, chronic hypertension, and preeclampsia/HELLP, were higher during the pandemic compared to pre-pandemic pregnancies. Pregnancy-induced APOs remained high across the pandemic, and

	Pre-Pandemic	Early Pandemic	Peak Pandemic	Late Pandemic	
Dates	June 2017-May 2019	October 2019-Feb 2020	March 2020-Feb 2021	Mar 2021- Sept 2021	
Total Sample	*n* = 14,632	*n* = 2350	*n* = 5640	*n* = 2822	
	n (%)	n (%)	n (%)	n (%)	*p*-value
Diabetes					
Gestational Diabetes	1589 (11.0)	381 (16.4)	677 (12.2)	340 (12.2)	< .001
Pre-existing Type II Diabetes	147 (1.0)	27 (1.2)	67 (1.2)	35 (1.2)	0.54
Chronic Hypertension	825 (5.6)	142 (6.0)	389 (6.9)	183 (6.5)	0.01
Pregnancy-induced Hypertension					
GH	1574 (11.3)	274 (12.3)	662 (12.5)	355 (13.3)	0.01
Preeclampsia/HELLP	768 (5.3)	202 (8.6)	473 (8.4)	262 (9.3)	< .001
Preterm Birth	1637 (11.2)	292 (12.4)	640 (11.4)	340 (12.1)	0.24

Table 2. Differences in pregnancy and birth outcomes by period by estimated conception date (n = 25,444)^ ^Comparisons across groups assessed using chi-square test. GH, gestational hypertension (no chronic or preeclampsia); Preeclampsia/HELLP includes Preeclampsia/Superimposed preeclampsia/Eclampsia/HELLP; preterm birth (< 37 weeks)

Dates Total Sample	Pre-Pandemic June 2017-May 2019 *n* = 14,632		Early Pandemic October 2019-Feb 2020 *n* = 2350		Peak Pandemic March 2020-Feb 2021 *n* = 5640		Late Pandemic Mar 2021-Sept 2021 *n* = 2822			
	RR	aRR	RR (95% CI)	aRR (95% CI)	RR (95% CI)	aRR (95% CI)	RR (95% CI)	aRR (95% CI)	RR *p*-value	aRR *p*-value
Diabetes										
Gestational Diabetes	Ref	Ref	1.50 (1.36, 1.67)	1.47 (1.33, 1.63)	1.11 (1.02, 1.21)	1.11 (1.02, 1.20)	1.11 (1.00, 1.24)	1.06 (0.95, 1.18)	< .001	< .001
Pre-existing Type II Diabetes	Ref	Ref	1.17 (0.78, 1.76)	1.02 (0.68, 1.54)	1.20 (0.90, 1.61)	1.12 (0.84, 1.50)	1.23 (0.85, 1.78)	1.09 (0.76, 1.58)	0.51	0.88
Chronic Hypertension	Ref	Ref	1.07 (0.90, 1.27	0.98 (0.83, 1.16)	1.24 (1.10, 1.39)	1.17 (1.05, 1.32)	1.16 (0.99, 1.36)	1.08 (0.93, 1.26)	0.005	0.046
Pregnancy-induced Hypertension										
GH[a]	Ref	Ref	1.08 (0.96, 1.22)	1.00 (0.89, 1.13)	1.12 (1.02, 1.22)	1.04 (0.95, 1.13)	1.19 (1.07, 1.32)	1.10 (0.99, 1.23)	0.01	0.34
Preeclampsia/HELLP	Ref	Ref	1.66 (1.43, 1.93)	1.54 (1.33, 1.78)	1.62 (1.45, 1.81)	1.48 (1.32, 1.65)	1.79 (1.57, 2.05)	1.62 (1.41, 1.85)	< .001	< .001
Preterm Birth	Ref	Ref	1.11 (0.99, 1.25)	1.09 (0.97, 1.23)	1.02 (0.94, 1.12)	1.02 (0.93, 1.11)	1.08 (0.96, 1.20)	1.09 (0.97, 1.21)	0.28	0.34

Table 3. Adverse pregnancy outcomes by period by estimated month of conception (*n* = 25,444)^ ^RR, relative risk; aRR, adjusted relative risk; CI, confidence interval; GH, gestational hypertension (no chronic or preeclampsia); Preeclampsia/HELLP includes Preeclampsia/Superimposed preeclampsia/Eclampsia/HELLP; preterm birth (< 37 weeks). [a]adjusted aRR from Robust Poisson adjusted for maternal age, parity, race/ethnicity, education, marital status, pre-pregnancy BMI, smoking status, average GWG; [b]models for pre-existing type-II diabetes and gestational hypertension limited to Asian, Black, Hispanic, and White participants due to insufficient data on Alaska Native/ Pacific Islander race/ethnicity.

chronic hypertension became more prevalent in mid-pandemic and did not return to pre-pandemic levels. Individuals with multiple conceptions saw these effects in early pandemic pregnancies, rather than their pre-pandemic pregnancy, suggesting these results are individual independent. In general, more individuals entered pregnancy with chronic conditions, and more were diagnosed with APOs during the pandemic compared to before the pandemic.

For our first aim, pregnant individuals experienced higher rates of APOs during the early and peak pandemic, which aligns with other disaster literature that stressful events impact perinatal health.[1,2] Early and peak pandemic were notably stressful for pregnant individuals, with stay-at-home orders, limited vaccine availability, and their high-risk status.[13] We did not find increases in preterm birth, though higher rates of preterm birth were found in other disaster literature,[6,7] and early pandemic investigations.[17] This difference may be due to our exploration of longer pandemic periods, and changes in stressors across the pandemic. The APOs affected were mainly GDM and preeclampsia/HELLP, in line with other early pandemic literature.[15,17,19–23] The current study adds to the literature that the GDM diagnosis increase has leveled off in the late pandemic. Higher prevalence of GDM and hypertension-related disorders may be from prolonged exposure of additional time spent sedentary

	Gestational Diabetes				Pre-eclampsia			
Overall	**OR**	**95% CI**	**aOR**	**95% CI**	**OR**	**95% CI**	**aOR**	**95% CI**
Pre-pandemic	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Post-pandemic	1.91	1.54–2.38	0.95	0.48–1.87	0.65	0.51–0.81	0.93	0.50–1.74
Pandemic Period								
Pre-pandemic	Ref	Ref	Ref	Ref	Ref	Ref	Ref	Ref
Early pandemic	3.78	2.07–6.89	3.26	1.52–6.97	0.92	0.52–1.60	1.48	0.73–2.98
Peak pandemic	1.96	1.40–2.74	1.50	0.72–3.14	0.76	0.53–1.09	1.49	0.76–2.93
Late pandemic	2.28	1.40–3.72	1.95	0.82–4.64	0.81	0.51–1.29	1.77	0.79–4.00

Table 4. Associations between pre-pandemic and post-pandemic pregnancies with gestational diabetes and preeclampsia diagnosis ($n = 3390$). ^Assessed using conditional logistic regression, adjusted models account for age, parity, and pre-pregnancy BMI; OR = Odds Ratio; aOR = adjusted Odds Ratio; *$p < 0.05$;

and food quality due to stay-at-home orders, which combined with stress may increase risk for hypertension.[38] This finding contrasts with other disaster literature, where food may be scarce (i.e., hurricane) or the stressful event may be relatively short-term (i.e., 9/11 disaster).[39,40] GDM typology may be varied, but there is consistent evidence that diet and physical activity play a role in its development and potential prevention.[41–43] These results indicate that the COVID-19 pandemic impacted different pregnancy-related outcomes compared to other major stressful events.

Our second hypothesis was partially supported, as more individuals entered pregnancy with chronic hypertension in the middle of the pandemic, however there was no change in type 2 diabetes prevalence. These findings complement our APO results, as these individuals experienced high stress and changes to daily life for up to a year prior to pregnancy,[44] which may have been the precursor for developing hypertension.[38] Pre-existing type 2 diabetes may be the result of low physical activity and unhealthy diet, but over an extended time frame (i.e., a decade).[45] The pandemic time frame investigated (2-years) may not be sufficient to develop this specific chronic condition. Reviews of longitudinal studies find that adults gained weight during the first year of the pandemic (~0.93 kg),[46] and having a higher weight status is associated with pre-diabetes,[47] which may translate to type 2 diabetes later in life. In a separate paper using this same cohort, we further explored higher weight status and found significant differences in APOs and chronic disease amongst Black and White pregnancy people with obesity (n = 7,431). Namely, black individuals were more likely to enter pregnancy with chronic conditions but had lower rates of APOs (e.g., GDM and preeclampsia) compared to White individuals.[48] When considering the full cohort in the current paper that includes all races and weight statuses, we did see an increase in GDM which is a known risk factor for later type 2 diabetes as well.[41] It is also possible that individuals could have undiagnosed type 2 diabetes as health care access was limited during early pandemic related to later pandemic. It is promising that there was no increase in pre-existing conditions in late pandemic, suggesting pandemic effects have become minimal.

Our hypothesis that individuals would have more APOs in their pandemic pregnancy had some support, as individuals with an early pandemic pregnancy had higher rates of GDM compared to their pre-pandemic pregnancy. These results build upon our other aim, as they indicate higher GDM diagnoses are independent of individuals pregnant at that time. Instead of participant characteristics, it is unclear if stress from the lockdown,[19] lifestyle changes (e.g., increased time spent sedentary), or both occurring in early pandemic and pregnancy may be driving these increased rates.[44] We did not find any major changes in preeclampsia in paired analysis. Higher pre-pregnancy BMI, and very young (< 18 years) and older ages (> 40 years) are risk factors for preeclampsia.[33] These participant characteristics may have explained a lower rate in pandemic pregnancies as after adjustment results were not significant. Nulliparity and history of preeclampsia are also important risk factors,[33] thus comparing preeclampsia across two pregnancies may not be equivalent experiences. Combined with our other results, these findings underscore supporting pregnant individuals during natural disasters and significant stressful events.

Strengths of this investigation include segmented and late period assessment across the COVID-19 pandemic, rigorous data extraction methods, within-individual analysis, examining pre-existing conditions, a larger pre-pandemic sample (i.e. 3-years vs. 1-year), and a variety of APOs explored. These components allowed thorough investigation of birthing individuals health across multiple pandemic phases. Some of the most severe APOs (death, severe morbidity, stillbirth) were too rare to be examined. Instead, we contribute to the literature developments related to APOs with an etiology of stress and health behaviors. Another consideration is assessment of the complex relationship between pre-pregnancy weight, gestational weight gain, APOs, and chronic disease development. Though the current analysis controlled for pre-pregnancy BMI as a covariate, further examination using advanced approaches and additional metabolic data may help untangle these pathways. One limitation is that this study was confined to one hospital within a southern U.S. state, and results may not generalize to other areas across the U.S. COVID-19 infection. Health behaviors were not captured but are important contributors to developing APOs and pre-existing conditions and should be explored in future studies.[49–52] Finally, results are confined to the 2-years post pandemic and may not capture APO changes beyond this time frame.

Conclusions

Pregnancy-induced APOs increased early pandemic, while middle to late pandemic pre-existing condition increased, relative to pre-pandemic. These results indicate that the COVID-19 pandemic influenced birthing individual's pregnancy outcomes and health in a different way than hurricanes or other natural disasters. Regardless, supporting birthing individuals amongst significant stressful events, especially in early gestation, is critical for preventing APOs and severe maternal morbidities and mortality in the future.

Data availability

The de identified study data may be available upon request.

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Author contributions

CLK contributed to initial manuscript creation, project management, and critical review of the final manuscript. EH contributed to study conception and design, obtaining funding, data acquisition, data analysis, data interpretation, and critical review of the final manuscript. NC contributed to data analysis, data interpretation, and critical review of the final manuscript. EFS contributed to study conception and design, obtained funding, data acquisition, data interpretation, initial manuscript creation, and critical review of the final manuscript. MK helped with study conception and design and obtaining funding. LMR contributed to conception and design, obtained funding, data acquisition, data interpretation, and critical review of the final manuscript.

Declarations

Competing interests

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Ethical approval

This study of electronic health record data was granted waivers of informed consent and HIPAA authorization and determined to be exempt by Woman's Hospital Foundation Institutional Review Board (FWA: 0005699; IRB Registration: 00003774). All methods were carried out following relevant guidelines and regulations for hospital delivery record data and abstracting medical records. Thus, this retrospective chart review did not include experimental protocols for approval by an ethics committee.

Additional information

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