Analysis of adverse pregnancy outcomes among pregnant women in Hunan Province from 2015 to 2023: Incidence, temporal trends, and risk factors

MA Jiezhi, CHEN Wenxiu, LIU Lingyi, YI Shuijing

(Department of Gynecology, Third Xiangya Hospital, Central South University, Changsha 410013, China)

ABSTRACT

Objective: In recent years, China has witnessed marked changes in the fertility environment and the composition of women of childbearing age, making the prevention and control of adverse pregnancy outcomes (APOs) a major challenge for maternal and infant health management. This study aims to investigate the incidence, trends, and risk factors for APOs in Hunan Province from 2015 to 2023.

Methods: This was a retrospective cohort study of 5 279 639 pregnancies in Hunan Province hospitals from January 2015 to December 2023 using a province-wide web-based maternal health registry. The APOs included preterm birth (subclassified by gestational age), late-term birth, and term low birth weight (LBW). Multivariable Logistic regression and interrupted time series analysis (ITSA) were used to assess associations and policy impacts.

Results: The incidence of APO increased from 7.18% (2015) to 9.01% (2023), with the prevalence of extreme preterm birth increasing by 95.71%. The highest risk was associated with multifetal pregnancy (adjusted *OR*=21.13, 95% *CI* 20.88 to 21.38; singleton pregnancy as the reference). Advanced maternal age (40−44 years: *OR*=1.96, 95% *CI* 1.92 to 2.00; maternal age 25−29 years as the reference) and caesarean delivery (*OR*=1.36, 95% *CI* 1.35 to 1.37) were significant predictors. ITSA revealed an accelerated increase in APO incidence following the policy implementation (β=0.003, P<0.001).

Conclusion: Demographic changes, including the increasing proportion of women of advanced maternal age, have contributed to the continuing rise in APOs. Targeted preventive interventions during pregnancy are urgently needed. These findings may provide evidence for the development of maternal health management policies in China and may also be applicable to comparable middle-income countries and regions.

KEY WORDS preterm birth; low birth weight; advanced maternal age; caesarean delivery; pregnancy complications; two-child policy

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First author: MA Jiezhi, Email: majiezhi0928@126.com, ORCID: 0009-0004-3124-8145

Corresponding author: YI Shuijing, associate chief physician, Email: yishuijing@126.com, ORCID: 0009-0009-4310-5703

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2015—2023年湖南省孕产妇不良妊娠结局分析：发生率、时间趋势及危险因素

马洁稚，陈文秀，刘玲熠，易水晶

(中南大学湘雅三医院妇科，长沙 410013)

[摘 要] 目的：近年来中国生育环境与育龄人群结构发生明显变化，不良妊娠结局防控成为母婴健康管理的重要挑战。本研究旨在探讨2015—2023年湖南省不良妊娠结局发生率、变化趋势及相关危险因素。**方法：**本研究为回顾性队列研究，依托全省孕产妇网络健康登记系统，纳入2015年1月至2023年12月湖南省各级医疗机构的5 279 639例妊娠病例。不良妊娠结局包括不同孕周分层早产儿、过期产儿、足月低出生体重儿。采用多因素Logistic回归分析与间断时间序列分析探究相关关联及政策干预效应。**结果：**湖南省不良妊娠结局发生率由2015年的7.18%上升至2023年的9.01%，极早早产发生率增幅达95.71%。多胎妊娠患病风险最高(校正*OR*=21.13，95% *CI* 20.88~21.38；以单胎妊娠为参照)；高龄产妇(40~44岁，*OR*=1.96，95% *CI* 1.92~2.00；以25~29岁产妇为参照)、剖宫产分娩(*OR*=1.36，95% *CI* 1.35~1.37)均为不良妊娠结局独立危险因素。间断时间序列分析显示，相关生育政策实施后不良妊娠结局出现加速上升的趋势(β=0.003，*P*<0.001)。**结论：**孕产妇高龄化等人口结构改变导致不良妊娠结局持续升高，亟需制定针对性孕期防控干预措施。本研究结果可为我国孕产妇健康管理政策的制订提供一定依据，且结论适用于同类中等收入国家与地区。

[关键词] 早产；低出生体重；高龄孕产妇；剖宫产；妊娠并发症；二孩政策

Adverse pregnancy outcomes (APOs), including preterm birth, late-term pregnancy, low birth weight (LBW), etc., pose significant health risks for pregnant women both during gestation and throughout their lifespan[1]. A prospective Drug Exposure and Birth Cohort (DEBC) study[2] conducted in China reports an overall incidence of adverse pregnancy outcomes at 13.49%, with preterm birth representing the most prevalent outcome at 5.15%. Preterm birth is defined as delivery occurring before 37 weeks of gestation and can be further classified based on gestational age: extremely preterm (less than 28 weeks), very preterm (28 to 31 weeks), moderately preterm (32 to 33 weeks), and late preterm (34 to 36 weeks) [3]. Late-term pregnancy, defined as birth at 42 weeks or more, is linked to higher risks of perinatal issues and increased neonatal intensive care unit (ICU) admissions[4]. Full-term LBW refers to births between 37 and 41^{+6} weeks with a weight under 2 500 g[5]. LBW infants account for 80% of global neonatal deaths, with two-thirds being preterm[6].

Despite global prevention efforts, preterm birth rates have remained stable from 2010 to 2020[7]. In China, research on APOs is limited, focusing mainly on preterm births, with little data on late-term births or LBW. A meta-analysis[8] examining the incidence and trends of preterm birth in China from 1990 to 2016 indicates a significant increase in preterm birth rates over the past three decades, rising from 5.36% during 1990—1994 to 7.04% in 2016, with an annual growth rate of 1.05%. The analysis also reveals regional disparities, with the highest rates reported in West China. Additionally, an observational study[9] involving over 9 million Chinese women from 2012 to 2018 found that the overall preterm birth rate rose from 5.9% in 2012 to 6.4% in 2018, with increases noted in both singleton and multiple pregnancies. Utilizing the heaping adjustment method, researchers estimated the incidence of LBW among children under 6 years of age in China to be 5.15% in 2013, which subsequently decreased to 4.57% for boys and 5.68% for girls[5]. Despite the availability of large-scale national sampling surveys that have analyzed the occurrence of APOs, no study has systematically investigated the prevalence of APOs across Hunan Province.

On October 29, 2015, China announced the two-child policy, effective in Hunan Province by July 2016[10], impacting the country's sociodemographic structure[11]. Women aged 35 and older face higher risks

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of birth defects and pregnancy complications, affecting both mothers and infants[12]. A study[13] showed congenital defect rates per 10 000 births rose from 245.95 in 2013 to 304.36 in 2017, with early gestation defects increasing from 1.29% to 11.45%. Despite known risks, there is a lack of extensive studies on how policy changes affect APOs. Specifically, research is scarce on the impact of the three-child policy on maternal dynamics and APOs at the provincial level over time. This study aims to investigate the incidence, trends, and risk factors for APOs in Hunan Province from 2015 to 2023.

1 Materials and methods

1.1 Ethics statements

This retrospective study was drawn on data from pregnant women in Hunan Province, covering the period from January 1, 2015, through December 31, 2023. Ethical approval for the research was granted by the Ethics Committee of the Third Xiangya Hospital (Approval number: 241053). Due to the retrospective, observational nature of this study and the use of anonymized, routinely collected administrative data from the province-wide registry, the requirement for individual informed consent was waived by the ethics committee.

1.2 Study design

This study gathered basic clinical details and obstetric records for pregnant and postnatal women treated in the obstetrics departments of the participating hospitals. Each hospital submitted its data using an online reporting system that is overseen by the National Office of Maternal and Child Health Monitoring based in Hunan. The complete flow of study population selection, detailing the number of records excluded at each stage, is presented in Figure 1. After applying sequential exclusion criteria to the initial dataset of 5 356 494 pregnancies, the final analytical cohort comprised 5 279 639 pregnancies.

1.3 Outcome measures

The primary focus of this study is the occurrence of APOs, including preterm birth, late-term birth, and term low birth weight. In accordance with the WHO guidelines[14], preterm birth is categorized as follows: Extremely preterm (delivery before 28 weeks of gestation), very preterm (28 to 31 weeks of gestation), moderately preterm (32 to 33 weeks of gestation), and late preterm (34 to 36 weeks of gestation). Late-term birth refers to deliveries at 42 weeks of gestation or later[15], whereas full-term low birth weight describes infants born between 37 and 41^{+6} weeks of gestation with a birth weight under 2 500 g[5].

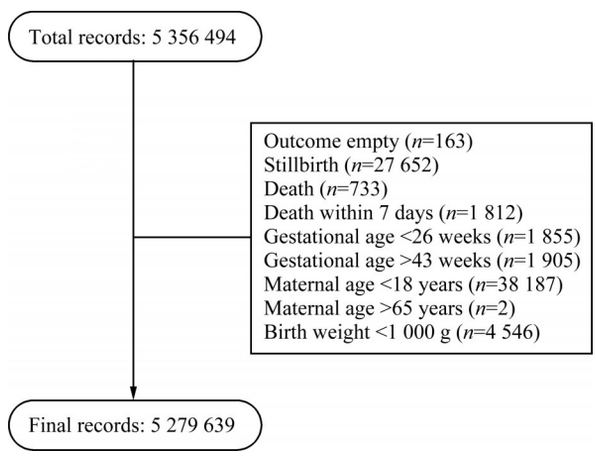


Figure 1 Flowchart of study population selection

This study analysed a range of sociodemographic and obstetric factors. Sociodemographic factors included type of residence during pregnancy (village or town), maternal education level (primary school or lower, middle school, high school, college or higher), hospital level (level 1−2 or level 3, determined by bed count, clinical department setup, medical staff numbers, equipment availability, and funding classification), maternal age (years), parity (primiparous or multiparous) and type of pregnancy (singleton or multiple)[9]. Obstetric factors included mode of delivery (vaginal or caesarean) and maternal complications (antepartum complications, medical disease, or others).

Antepartum complications included conditions such as placenta previa, placental abruption, premature rupture of membranes, polyhydramnios, gestational hypertension, gestational diabetes, and hyperemesis gravidarum, among others[16]. Medical complications included heart disease, liver disease, anaemia, gastric disorders (gastroenteritis, peptic ulcers), urinary system

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conditions (pyelonephritis, stones, infections), and acquired immunodeficiency syndrome[17].

To examine geographical variation, From January 1, 2015, to December 31, 2023, we calculated the crude incidence of overall APOs for each prefecture-level city in Hunan Province by dividing the number of APO cases by the total number of deliveries in that city over the study period. This included the number of APOs and APO rates across all pregnancies, as well as separate counts and rates for singleton versus multiple pregnancies and for primiparous versus multiparous women. We also counted APO occurrences and calculated their incidence for the total population and subgroups, stratified by maternal sociodemographic and obstetric characteristics. The APO rate was calculated as the number of live births with APOs divided by the total number of births.

1.4 Statistical analysis

All the statistical analyses were performed using R version 4.4.3. A provincial map was then generated using QGIS software (version 3.28) to visualize the spatial distribution of APO incidence, with a color gradient representing the rate range.

Categorical variables were presented as frequencies (percentages). The associations between maternal sociodemographic and obstetric characteristics and both overall APOs and APOs in each subgroup was analysed by Logistic regression models to explore these links. Given the exploratory nature of this study, the models included all known sociodemographic and obstetric factors related to APOs, which were collected using the online system. First, we estimated the crude odds ratio (*OR*) and their 95% confidence interval (*CI*) for each factor. Second, we used two multivariate Logistic regression models to calculate ORs adjusted for potential confounding variables. Model 1 was adjusted for maternal sociodemographic factors, including region, hospital level, age, parity, pregnancy type (singleton vs. multiple) and delivery method. Model 2 was built on Model 1 by further adjusting for obstetric complications. For variables with missing data, we retained missing data as a separate category in the categorical variable for multivariable analysis.

To investigate trends in overall and subgroup-specific APO rates during the study period, along with changes in the proportional distribution of maternal sociodemographic and obstetric characteristics, we identified factors that might be related to APO trends. These factors included maternal age, multiple pregnancies, caesarean section and obstetric complications. We used the prop.trend.test function in R 4.4.3 to perform Cochran-Armitage tests to examine whether these indicators showed linear trends over time. The study period coincided with the implementation of China's universal two-child policy, and we hypothesized that this policy adjustment might affect APO trends. We therefore used interrupted time series analysis (ITSA) combined with ordinary least squares regression models with autocorrelation correction to examine changes in monthly preterm birth rates before and after the policy was implemented. The effective date of the universal two-child policy was set as July 1, 2016, nine months after the policy was announced on October 29, 2015. Potential confounding variables included in the analysis were maternal age and multiple pregnancies. $P<0.05$ was considered to indicate statistical significance.

2 Results

2.1 Incidence and temporal trends of APOs (2015—2023)

In 5 279 639 pregnancies cohort, 5 133 047 pregnancies (97.22%) were singleton gestations, and 146 592 (2.78%) were multiple gestations. Primiparous women accounted for 2 497 890 cases (47.31%), whereas multiparous women accounted for 2 781 749 cases (52.69%). APOs occurred in 403 009 women (7.63%). The specific APO distribution was as follows: 1 119 (0.02%) extremely preterm births, 19 812 (0.38%) very preterm births, 32 084 (0.61%) moderate preterm births, 247 322 (4.68%) late preterm births, 18 895 (0.36%) late-term births, and 83 777 (1.59%) full-term LBW infants. The APO incidence was 6.05% for singleton pregnancies and 63.20% for multiple pregnancies. Among primiparous women, the APO rate was 8.34%, whereas it was 7.00% for multiparous women (Table 1).

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Table 1 Overall APOs in singleton and multiple pregnancies and in primiparous and multiparous women in Hunan Province, China, 2015—2023

Variables	All pregnancies (*n*=5 279 639)							
	Normal	Extremely preterm	Very preterm	Moderate preterm	Late preterm	Late-term	Full-term LBW	APO
Values/[No.(%)]	4 876 630 (92.37)	1 119 (0.02)	19 812 (0.38)	32 084 (0.61)	247 322 (4.68)	18 895 (0.36)	83 777 (1.59)	403 009 (7.63)
2015—2023 change/%	−1.96	95.71	48.09	63.68	57.03	−93.08	1.36	25.37
Annual increase rate/% (95% *CI*)	−0.28 (−0.36 to −0.19)	10.99 (7.15 to 14.96)	4.94 (4.10 to 5.79)	5.99 (4.81 to 7.18)	5.77 (5.18 to 6.37)	−28.30 (−30.42 to −26.11)	1.33 (−1.06 to 3.78)	3.26 (2.28 to 4.25)
Variables	Singleton pregnancies (*n*=5 133 047)							
	Normal	Extremely preterm	Very preterm	Moderate preterm	Late preterm	Late-term	Full-term LBW	APO
Values/[No.(%)]	4 822 681 (93.95)	841 (0.02)	14 472 (0.28)	22 679 (0.44)	190 197 (3.71)	18 861 (0.37)	63 316 (1.23)	310 366 (6.05)
2015—2023 change/%	−1.04	100.00	32.61	55.17	49.48	−92.98	−0.04	16.35
Annual increase rate/% (95 *CI*)	−0.15 (−0.24 to −0.07)	10.88 (7.19 to 14.70)	3.87 (2.68 to 5.07)	5.11 (4.14 to 6.08)	5.09 (4.35 to 5.84)	−28.16 (−30.30 to −25.95)	1.16 (−1.62 to 4.01)	2.30 (1.04 to 3.57)
Variables	Multiple pregnancies (*n*=146 592)							
	Normal	Extremely preterm	Very preterm	Moderate preterm	Late preterm	Late-term	Full-term LBW	APO
Values/[No.(%)]	53 949 (36.80)	278 (0.19)	5 340 (3.64)	9 405 (6.42)	57 125 (38.97)	34 (0.02)	20 461 (13.96)	92 643 (63.20)
2015—2023 change/%	−21.83	28.75	47.15	31.54	31.47	−100.00	−24.76	16.02
Annual increase rate/% (95% *CI*)	−2.87 (−3.62 to −2.10)	5.88 (−1.36 to 13.65)	3.12 (0.32 to 5.99)	3.03 (1.41 to 4.67)	3.13 (2.25 to 4.03)	−44.17 (−59.59 to −22.87)	−2.80 (−3.76 to −1.84)	1.74 (1.19 to 2.29)
Variables	Primiparous women (*n*=2 497 890)							
	Normal	Extremely preterm	Very preterm	Moderate preterm	Late preterm	Late-term	Full-term LBW	APO
Values/[No.(%)]	2 289 587 (91.66)	657 (0.03)	10 831 (0.43)	16 760 (0.67)	123 083 (4.93)	8 755 (0.35)	48 217 (1.93)	208 303 (8.34)
2015—2023 change/%	−2.20	128.97	46.93	61.01	51.87	−95.15	13.94	26.76
Annual increase rate/% (95% *CI*)	−0.31 (−0.37 to −0.25)	13.48 (7.87 to 19.39)	5.65 (4.38 to 6.93)	5.92 (4.67 to 7.18)	5.40 (4.71 to 6.10)	−31.37 (−34.08 to −28.54)	2.50 (0.91 to 4.12)	3.40 (2.79 to 4.01)
Variables	Multiparous women (*n*=2 781 749)							
	Normal	Extremely preterm	Very preterm	Moderate preterm	Late preterm	Late-term	Full-term LBW	APO
Values/[No.(%)]	2 587 043 (93.00)	462 (0.02)	8 981 (0.32)	15 324 (0.55)	124 239 (4.47)	10 140 (0.36)	35 560 (1.28)	194 706 (7.00)
2015—2023 change/%	−1.91	66.17	58.79	72.11	65.87	−91.49	−9.03	26.82
Annual increase rate/% (95% *CI*)	−0.25 (−0.35 to −0.16)	7.79 (4.24 to 11.47)	4.45 (2.67 to 6.25)	6.26 (4.74 to 7.80)	6.28 (5.50 to 7.08)	−26.22 (−28.38 to −23.99)	0.03 (−2.83 to 2.98)	3.25 (2.06 to 4.45)

Normal: Born between 37- and 41^{+6}- weeks' gestation, and body weight ≥2 500 g; Extremely preterm: Born <28 weeks' gestation; Very preterm: Born between 28- and 31- weeks' gestation; Moderate preterm: Born between 32- and 33- weeks' gestation; Late preterm: Born between 34- and 36- weeks' gestation; Late-term: Born ≥42 weeks' gestation; Full-term LBW: Born between 37- and 41^{+6} -weeks' gestation, and body weight <2 500 g. APO: Adverse pregnancy outcome; LBW: Low birth weight.

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The overall APO incidence increased significantly from 7.18% in 2015 to 9.01% in 2023, representing a 25.37% increase, with an annual increase rate (ARI) of 3.26% (95% *CI* 2.28% to 4.25%; Table 1). Within the preterm birth subgroup, substantial increases were observed. Extremely preterm births increased by 95.71% (ARI=10.99%, 95% *CI* 7.15% to 14.96%), very preterm births by 48.09% (ARI=4.94%, 95% *CI* 4.10% to 5.79%), moderate preterm births by 63.68% (ARI= 5.99%, 95% *CI* 4.81% to 7.18%), and late preterm births by 57.03% (ARI=5.77%, 95% *CI* 5.18% to 6.37%). The late-term birth subgroup decreased significantly by 93.08% (ARI=−28.30%, 95% *CI* −30.42% to −26.11%).

Among singleton pregnancies, the overall APO incidence increased significantly by 16.35% (ARI= 2.30%, 95% *CI* 1.04% to 3.57%). The extremely preterm subgroup exhibited the greatest increase in APO, whereas the late-term subgroup showed a decrease (Table 1). For multiple pregnancies, the overall APO incidence increased significantly from 57.68% in 2015 to 66.92% in 2023, a 16.02% increase (ARI= 1.74%, 95% *CI* 1.19% to 2.29%). Compared with the other preterm subgroups, the very preterm subgroup demonstrated a markedly greater increase (Supplementary Table 1, https://doi.org/10.57760/sciencedb.xbyxb.00170). APO rates decreased in both the late-term and full-term LBW subgroups for multiple pregnancies (Table 1).

The overall APO incidence among primiparous women increased significantly by 26.76%, rising from 7.61% in 2015 to 9.65% in 2023 (ARI=3.40%, 95% *CI* 2.79% to 4.01%). APO rates increased across all the subgroups except for late-term births, with the extremely preterm subgroup showing the greatest increase. Multiparous women exhibited a similar trend in overall APO incidence, although the full-term LBW subgroup rate remained unchanged (Table 1).

Stratified by parity, the APO incidence increased from 7.61% to 9.65% among primiparous women and from 6.64% to 8.42% among multiparous women between 2015 and 2023 (Supplementary Table 1). The absolute increase was larger in multiparous women (1.78%) than in primiparous women (2.04%), suggesting that the policy-induced increase in multiparous pregnancies may have contributed to the overall APO rise.

2.2 Risk factors associated with APOs (2015—2023)

Among the 5 279 639 women, 3 916 742 (74.20%) resided in village areas, and 3 870 981 (73.30%) delivered at level 1 − 2 hospitals. The majority have completed compulsory education (Table 2). Women with lower educational attainment, who were aged <20 or > 35 years, who were primiparous, who had multiple pregnancies, who were undergoing caesarean delivery, or who had experienced antepartum complications demonstrated higher overall APO rates, exceeding 8% (Table 2).

Multiple pregnancy showed the strongest association with APOs (*OR*=26.68, 95% *CI* 26.39 to 26.98), followed by advanced maternal age (≥45 years: *OR*= 3.48, 95% *CI* 3.32 to 3.64) and caesarean delivery (*OR*= 2.06, 95% *CI* 2.05 to 2.08). Tertiary hospital delivery (*OR*=2.03, 95% *CI* 2.02 to 2.04) and antepartum complications (*OR*=2.12, 95% *CI* 2.10 to 2.14) were also associated with increased APO risk, whereas multiparity was associated with reduced risk (*OR*=0.83, 95% *CI* 0.82 to 0.83; Table 2).

Compared with women who gave birth in 2015, those who delivered in 2023 were more likely to reside in urban areas during pregnancy (25.13% in 2015, 30.20% in 2023; Figure 2A), choose tertiary hospitals for delivery (15.53% in 2015, 42.02% in 2023; Figure 2B), complete compulsory education (11.38% in 2015, 64.03% in 2023; Figure 2C), be over 35 years old (8.12% in 2015, 18.33% in 2023; Figure 2D), be multiparous (43.89% in 2015, 52.13% in 2023; Figure 2E), have multiple pregnancies (2.34% in 2015, 3.43% in 2023; Figure 2F), experience prenatal complications (3.69% in 2015, 27.03% in 2023), and suffer from medical conditions (0.94% in 2015, 7.53% in 2023; Figure 2H). However, they had a lower probability of vaginal delivery (61.26% in 2015, 51.20% in 2023; Table 2, Figure 2G; Supplementary Table 2, https://doi.org/10.57760/sciencedb. xbyxb. 00170). Additionally, from 2015 to 2023, the number of women under 30 years old decreased by approximately 40%, whereas the number of women aged 30 − 34 increased (Figure 2D; Supplementary Table 2). A similar trend was observed among both primiparous and multiparous women. In 2023, both multiparous and primiparous women were more likely to have multiple pregnancies and opt for caesarean section (Figure 2; Supplementary Table 2).

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Table 2 Maternal sociodemographic and obstetric characteristics of all pregnancies in Hunan Province, China, 2015—2023 (*n*=5 279 639)

Variables	Values/ [No.(%)]	c*OR* (95% *CI*)						
		APO	Extremely preterm	Very preterm	Moderate preterm	Late preterm	Late-term	Full-term LBW
Type of residence during pregnancy								
Village	3 916 742 (74.20)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
Town	1 362 897 (25.80)	1.13 (1.12 to 1.14)	1.51 (1.33 to 1.71)	1.31 (1.27 to 1.35)	1.29 (1.26 to 1.32)	1.23 (1.22 to 1.24)	0.35 (0.34 to 0.37)	0.96 (0.95 to 0.98)
Hospital level								
Level 1−2	3 870 981 (73.30)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
Level 3	1 408 650 (26.70)	2.03 (2.02 to 2.04)	6.67 (5.87 to 7.57)	6.29 (6.10 to 6.48)	4.58 (4.48 to 4.68)	2.13 (2.11 to 2.14)	0.24 (0.22 to 0.25)	1.29 (1.28 to 1.31)
No data	8 (0.00)							
Maternal education								
Primary school or lower	204 586 (3.90)	1.02 (1.00 to 1.04)	1.06 (0.77 to 1.45)	1.01 (0.94 to 1.09)	0.98 (0.93 to 1.04)	0.95 (0.92 to 0.97)	1.09 (0.98 to 1.22)	1.27 (1.22 to 1.32)
Middle school	1 216 615 (23.00)	1.01 (1.00 to 1.02)	1.14 (0.95 to 1.36)	0.97 (0.93 to 1.01)	1.00 (0.97 to 1.03)	0.98 (0.97 to 1.00)	1.51 (1.42 to 1.60)	1.06 (1.03 to 1.08)
High school	875 577 (16.60)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
College or higher	403 725 (7.60)	0.96 (0.95 to 0.98)	1.28 (1.02 to 1.61)	0.97 (0.92 to 1.03)	0.92 (0.88 to 0.97)	1.00 (0.99 to 1.02)	0.45 (0.40 to 0.50)	0.91 (0.89 to 0.94)
No data	2 579 136 (48.90)							
Maternal age/years								
<20	108 404 (2.10)	1.26 (1.23 to 1.28)	0.80 (0.47 to 1.35)	1.38 (1.25 to 1.52)	1.24 (1.14 to 1.34)	1.04 (1.01 to 1.07)	1.85 (1.72 to 2.00)	1.68 (1.61 to 1.74)
21−24	977 833 (18.50)	0.99 (0.98 to 1.00)	0.80 (0.65 to 0.97)	0.85 (0.81 to 0.89)	0.88 (0.85 to 0.91)	0.90 (0.89 to 0.92)	1.40 (1.36 to 1.46)	1.19 (1.17 to 1.22)
25−29	2 113 859 (40.00)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
30−34	1 435 870 (27.20)	1.25 (1.24 to 1.26)	1.52 (1.31 to 1.76)	1.46 (1.41 to 1.51)	1.44 (1.41 to 1.48)	1.35 (1.33 to 1.36)	0.71 (0.68 to 0.74)	1.02 (1.00 to 1.04)
35−39	523 194 (9.90)	1.61 (1.59 to 1.62)	2.49 (2.10 to 2.96)	2.14 (2.05 to 2.23)	2.04 (1.97 to 2.11)	1.78 (1.75 to 1.80)	0.71 (0.67 to 0.76)	1.11 (1.08 to 1.14)
40−44	109 071 (2.10)	1.99 (1.95 to 2.03)	2.35 (1.70 to 3.26)	2.62 (2.44 to 2.82)	2.65 (2.50 to 2.81)	2.23 (2.18 to 2.28)	0.90 (0.81 to 1.00)	1.27 (1.21 to 1.33)
>45	11 408 (0.20)	3.48 (3.32 to 3.64)	2.47 (0.93 to 6.57)	4.03 (3.35 to 4.83)	4.84 (4.24 to 5.51)	4.09 (3.88 to 4.32)	1.06 (0.77 to 1.46)	1.88 (1.67 to 2.12)

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Table 2 (continued)

Variables	Values/ [No.(%)]	c*OR* (95% *CI*)						
		APO	Extremely preterm	Very preterm	Moderate preterm	Late preterm	Late-term	Full-term LBW
Parity								
Primiparous	2 497 890 (47.30)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
Multiparous	2 781 749 (52.70)	0.83 (0.82 to 0.83)	0.62 (0.55 to 0.70)	0.73 (0.71 to 0.75)	0.81 (0.79 to 0.83)	0.89 (0.89 to 0.90)	1.03 (1.00 to 1.05)	0.65 (0.64 to 0.66)
Type of pregnancy								
Singleton	5 133 047 (97.20)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
Multiple	146 592 (2.80)	26.68 (26.39 to 26.98)	29.66 (25.89 to 33.97)	32.98 (31.93 to 34.07)	37.07 (36.14 to 38.03)	26.85 (26.51 to 27.19)	0.16 (0.12 to 0.23)	28.89 (28.38 to 29.41)
Mode of delivery								
Vaginal	2 979 491 (56.40)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
Caesarean	2 300 148 (43.60)	2.06 (2.05 to 2.08)	0.49 (0.43 to 0.56)	1.58 (1.54 to 1.63)	2.40 (2.35 to 2.46)	2.31 (2.29 to 2.33)	0.90 (0.87 to 0.93)	1.86 (1.84 to 1.89)
Maternal complications								
No complications	4 363 224 (82.60)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
Antepartum complications	669 091 (12.70)	2.12 (2.10 to 2.14)	2.02 (1.75 to 2.34)	2.92 (2.83 to 3.02)	3.00 (2.93 to 3.08)	2.30 (2.28 to 2.33)	0.29 (0.27 to 0.31)	1.67 (1.65 to 1.70)
Medical disease	180 454 (3.40)	0.91 (0.89 to 0.93)	0.93 (0.66 to 1.33)	1.25 (1.16 to 1.35)	1.17 (1.10 to 1.24)	0.94 (0.91 to 0.96)	0.24 (0.21 to 0.28)	0.86 (0.82 to 0.90)
Others	66 869 (1.30)	1.46 (1.42 to 1.50)	2.66 (1.88 to 3.79)	2.31 (2.10 to 2.54)	2.03 (1.87 to 2.19)	1.52 (1.47 to 1.57)	0.37 (0.30 to 0.45)	1.22 (1.16 to 1.30)
No data	1 (0.00)							

c*OR*: Crude odds ratio.

Between 2015 and 2023, the incidence of singleton pregnancies substantially increased in the extremely preterm (100.00%), very preterm (32.61%), moderately preterm (55.17%), and late preterm (49.48%) subgroups (all P<0.001, Figure 3; Supplementary Table 3, https://doi.org/10.57760/sciencedb.xbyxb.00170). During the same period, significant increases occurred among singleton pregnancies for mothers aged ⩾35 years (124.22%), caesarean delivery (25.32%), antepartum complications (659.90%), and medical diseases (707.12%) (all P<0.001; Figure 3; Supplementary Table 3). Similar patterns of change were observed for both primiparous (Supplementary Table 4) and multiparous (Supplementary Table 5) women with singleton pregnancies. Among primiparous women, the incidence of full-term LBW also increased (11.71%, P<0.001; Supplementary Table 4).

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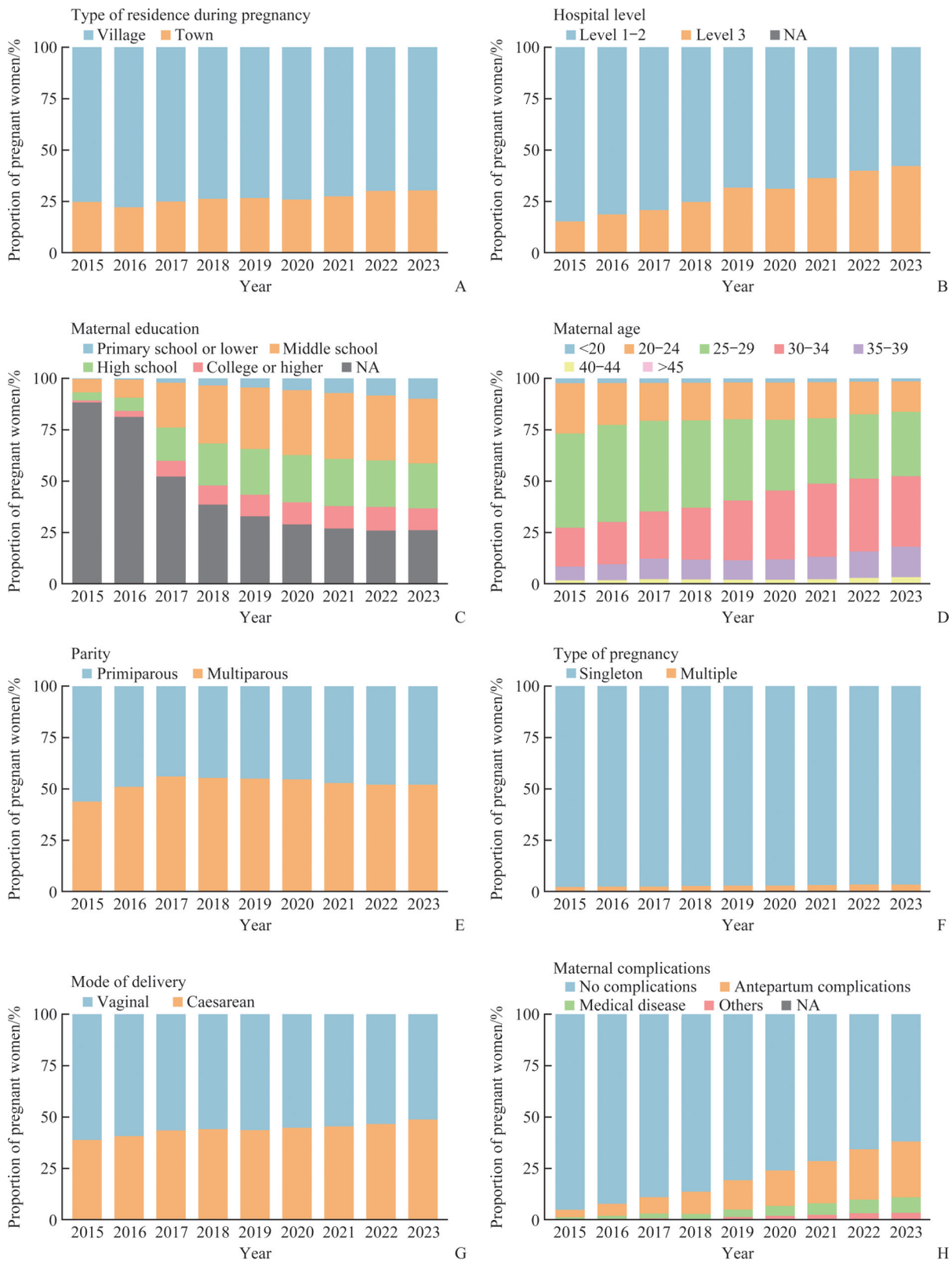


Figure 2 Changes factors associated with APO in all pregnancies in Hunan Province, China, 2015—2023

A－H: Type of residence during pregnancy (A), hospital level (B), maternal education (C), maternal age (D), parity (E), type of pregnancy (F), mode of delivery (G), maternal complications (H). Antepartum complications including placenta previa, placental abruption, premature rupture of membranes, polyhydramnios, gestational hypertension, gestational diabetes mellitus, and hyperemesis gravidarum. Medical complications including heart disease, liver disorders, anemia, gastric conditions (gastritis and peptic ulcer), urinary disorders (pyelonephritis, calculi, and infections), and acquired immunodeficiency syndrome. APO: Adverse pregnancy outcome; NA: Not available.

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The type of residence during pregnancy, hospital level, maternal age, parity status, pregnancy type, mode of delivery, and maternal complications were significantly associated with specific adverse pregnancy outcome subgroups (Table 3; Supplementary Table 6). The strongest association with APOs was observed for multiple pregnancies. In Model 2, compared with singleton pregnancies, multiple pregnancies were associated with approximately 21.13 times greater odds of APOs (Table 3; Supplementary Table 6, https://doi.org/10.57760/sciencedb.xbyxb.00170). Maternal age was the second most significant risk factor. This association was particularly pronounced for extremely preterm birth, where women aged 40–44 years had 20 times greater odds (Model 1) and 15.7 times greater odds (Model 2) than the reference group did (Table 3; Supplementary Table 6). Urban residence was associated with a slightly lower overall APO risk than rural residence, but was associated with a higher risk for extremely preterm birth. APO risk also varied by hospital level, with tertiary hospitals showing significantly higher risk than primary/secondary hospitals did, particularly for the extremely preterm subgroup. Compared with primiparous women, multiparous women exhibited a slightly lower overall APO risk. Specifically, multiparity was associated with a 94% reduction in the risk of extremely preterm birth (adjusted *OR*=0.06, 95% *CI* 0.04 to 0.08) and a 22% reduction in the risk of full-term LBW (adjusted *OR*=0.78, 95% *CI* 0.77 to 0.79). However, compared with primiparous women, multiparous women had higher risks for very preterm birth and late-term birth. Caesarean delivery was associated with a 1.36-fold higher overall APO risk than vaginal delivery was, with notable risks for the moderate preterm, late preterm, and full-term LBW subgroups. Conversely, vaginal delivery was associated with increased risks of extremely preterm, very preterm, and late-term birth.

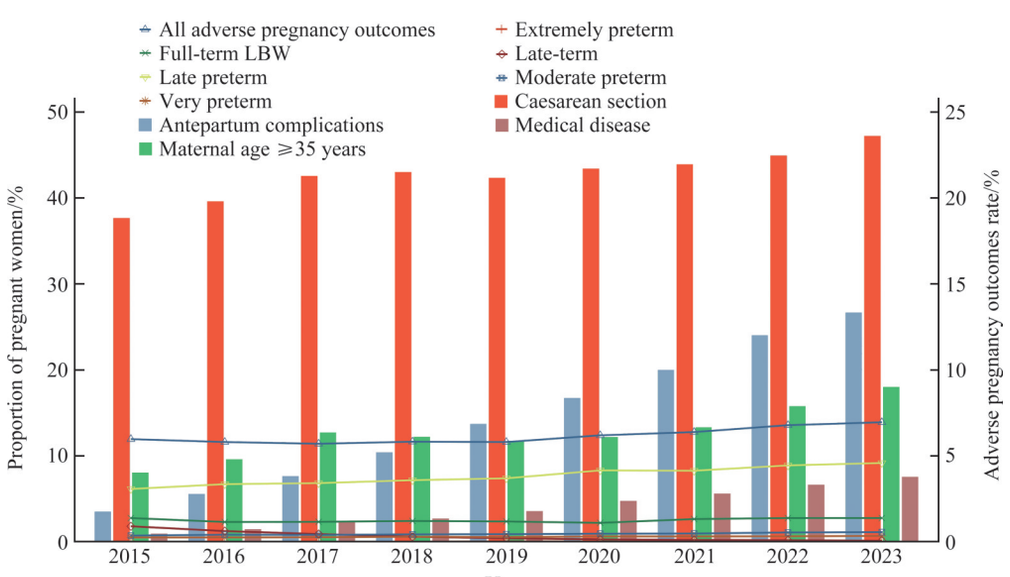


Figure 3 Changes in adverse birth rates, advanced maternal age, and obstetric factors associated with APO in all pregnancies in Hunan Province, China, 2015—2023

Extremely preterm was born <28 weeks' gestation. Very preterm was born between 28 and 31 weeks' gestation. Moderate preterm was born between 32 and 33 weeks' gestation. Late preterm was born between 34 and 36 weeks' gestation. Late-term was born between ⩾42 weeks' gestation. Full-term LBW was born between 37- and 41^{+6}- weeks' gestation, and body weight <2 500 g. LBW: Low birth weight.

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Table 3 Multivariable-adjusted associations between maternal characteristics and overall APO (Model 2: Further adjusted for obstetric complications)

Variables	*cOR* (95% *CI*)						
	APO	Extremely preterm	Very preterm	Moderate preterm	Late preterm	Late-term	Full-term LBW
Type of residence during pregnancy							
Village	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
Town	0.88 (0.87 to 0.89)	0.34 (0.31 to 0.38)	0.73 (0.71 to 0.76)	0.82 (0.80 to 0.84)	0.94 (0.93 to 0.95)	0.46 (0.44 to 0.49)	0.88 (0.86 to 0.89)
Hospital level							
Level 1−2	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
Level 3	1.66 (1.65 to 1.67)	—	5.44 (5.27 to 5.62)	3.53 (3.45 to 3.61)	1.71 (1.69 to 1.72)	0.29 (0.27 to 0.30)	1.09 (1.07 to 1.10)
Maternal age/years							
<20	1.62 (1.58 to 1.66)	1.49 (1.09 to 2.04)	2.41 (2.19 to 2.65)	2.42 (2.24 to 2.61)	1.31 (1.27 to 1.36)	2.22 (2.08 to 2.38)	2.00 (1.92 to 2.08)
21−24	1.15 (1.14 to 1.16)	0.05 (0.03 to 0.08)	1.09 (1.04 to 1.14)	1.36 (1.31 to 1.40)	1.04 (1.02 to 1.05)	1.33 (1.28 to 1.38)	1.31 (1.28 to 1.33)
25−29	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
30−34	1.10 (1.09 to 1.11)	0.81 (0.70 to 0.94)	1.31 (1.26 to 1.36)	1.33 (1.29 to 1.37)	1.13 (1.12 to 1.15)	0.82 (0.79 to 0.85)	0.93 (0.91 to 0.94)
35−39	1.43 (1.42 to 1.45)	11.94 (10.68 to 13.35)	2.33 (2.23 to 2.44)	1.77 (1.71 to 1.84)	1.52 (1.50 to 1.54)	0.69 (0.65 to 0.74)	1.11 (1.09 to 1.14)
40−44	1.88 (1.84 to 1.92)	15.70 (13.09 to 18.84)	1.85 (1.69 to 2.03)	4.01 (3.81 to 4.22)	1.92 (1.87 to 1.97)	1.03 (0.92 to 1.15)	1.28 (1.22 to 1.34)
>45	2.20 (2.08 to 2.32)	1.00 (0.18 to 5.61)	0.11 (0.04 to 0.27)	5.47 (4.91 to 6.08)	2.56 (2.41 to 2.72)	0.00 (0.00 to 47109.10)	0.70 (0.60 to 0.83)
Parity							
Primiparous	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
Multiparous	0.93 (0.93 to 0.94)	0.20 (0.18 to 0.22)	0.89 (0.86 to 0.92)	1.00 (0.97 to 1.02)	0.97 (0.96 to 0.98)	1.07 (1.04 to 1.10)	0.78 (0.77 to 0.79)
Type of pregnancy							
Singleton	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
Multiple	21.13 (20.88 to 21.38)	35.21 (30.88 to 40.14)	28.52 (27.49 to 29.59)	27.28 (26.54 to 28.05)	20.30 (20.03 to 20.58)	0.00 (0.00 to 0.00)	25.39 (24.91 to 25.89)
Mode of delivery							
Vaginal	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
Caesarean	1.33 (1.32 to 1.34)	0.11 (0.09 to 0.12)	0.75 (0.73 to 0.78)	1.20 (1.17 to 1.23)	1.47 (1.45 to 1.48)	0.96 (0.94 to 0.99)	1.34 (1.32 to 1.36)
Maternal complications							
No complications	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
Antepartum complications	1.69 (1.67 to 1.70)	0.59 (0.52 to 0.68)	2.17 (2.10 to 2.24)	2.01 (1.96 to 2.06)	1.81 (1.79 to 1.83)	0.96 (0.91 to 1.01)	1.49 (1.46 to 1.52)
Medical disease	0.78 (0.77 to 0.80)	0.31 (0.21 to 0.45)	1.07 (0.99 to 1.15)	0.89 (0.83 to 0.95)	0.79 (0.77 to 0.81)	0.45 (0.40 to 0.52)	0.70 (0.67 to 0.73)
Others	0.98 (0.95 to 1.00)	0.12 (0.07 to 0.22)	1.19 (1.08 to 1.30)	0.86 (0.79 to 0.93)	0.97 (0.94 to 1.00)	0.00 (0.00 to 0.06)	0.99 (0.93 to 1.05)

Model 2 was adjusted for maternal sociodemographic factors (residence, hospital level, maternal age, parity, pregnancy type, and mode of delivery) and obstetric complications (antepartum complications, medical diseases, and others). Detailed stratified analyses for each specific adverse pregnancy outcome (extremely preterm, very preterm, moderate preterm, late preterm, late-term, and full-term low birth weight) are presented in Supplementary Table 6 (https://doi.org/10.57760/sciencedb.xbyxb.00170).

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After adjusting for maternal sociodemographic characteristics, women with antepartum complications had approximately 1.69 times greater odds of having an APO than those without such complications did (adjusted *OR*=1.69, 95% *CI* 1.67 to 1.70; Table 3). The highest risks associated with antepartum complications were observed for the very preterm and moderate preterm subgroups (Table 3; Supplementary Table S6, https://doi.org/10.57760/sciencedb.xbyxb.00170).

Between 2015 and 2023, a significant increase in the number of women with antepartum complications and medical diseases occurred. The number of women with antepartum complications increased from 9 454 to 28 656, representing a 203.11% increase (Table 4). Similarly, the number of women with medical diseases increased from 2 847 to 8 523, highlighting a 199.37% increase (Table 4). Among singleton pregnancies in women aged 25 – 29 years with antepartum complications, adverse birth rates decreased significantly across preterm subgroups: extremely preterm (−17.92%, *P*<0.001), very preterm (−40.31%, *P*<0.05), moderately preterm (−26.84%, *P*<0.001), and late preterm (−3.85%, *P*<0.001). The most substantial decline was observed in the late-term subgroup (−99.00%, *P*<0.01; Table 4). Caesarean delivery rates demonstrated contrasting trends based on gestational age. Rates significantly decreased for deliveries before 28 weeks (−60.00%, *P*<0.05) but increased for deliveries between 28 and 31 weeks (3.79%, *P*<0.05; Table 4). Stratified analyses by parity revealed similar patterns regarding the relationships among abnormal pregnancy outcomes, adverse birth rates, and caesarean rates (Supplementary Tables 7 and 8, https://doi.org/10.57760/sciencedb.xbyxb.00170). However, primiparous women exhibited a significant increase in adverse birth rates, specifically within the full-term LBW subgroup (8.57%, *P*<0.001; Supplementary Table 7).

Table 4 Changes in adverse birth rates and caesarean section rates stratified by obstetric complications in singleton pregnancies in women aged 25–29 years in Hunan Province, China, 2015—2023

Variables	Year									*P* value for trend
	2015	2016	2017	2018	2019	2020	2021	2022	2023	
Antepartum complications (*n*=222 464)										
Number of deliveries	9 454	20 566	24 120	27 571	30 786	27 683	25 898	27 730	28 656	
Caesarean section rate/%										
<28 weeks	50.00	—	66.67	40.00	55.56	33.33	33.33	0.00	20.00	0.034
28–31 weeks	65.08	52.54	56.72	60.13	59.42	63.93	66.09	63.21	67.54	0.027
32–33 weeks	70.65	64.07	65.02	65.49	64.31	62.93	57.84	70.73	66.67	0.859
24–36 weeks	65.42	52.85	59.90	57.48	59.06	58.32	58.23	56.10	56.33	0.154
≤42 weeks	60.61	47.22	47.46	47.62	70.59	53.85	33.33	30.00	50.00	0.147
37 and 41^{+6} weeks and body weight <2 500 g	64.32	52.42	53.94	54.97	58.27	54.99	54.66	53.78	55.86	0.529
Adverse birth rate/%										
Extremely preterm	0.02	0.00	0.01	0.02	0.03	0.02	0.02	0.02	0.02	<0.001
Very preterm	0.67	0.57	0.56	0.55	0.45	0.44	0.44	0.38	0.40	0.023
Moderate preterm	0.97	0.81	1.01	0.82	0.83	0.74	0.79	0.59	0.71	<0.001
Late preterm	5.93	6.15	6.05	5.79	5.32	5.73	5.70	5.70	5.71	<0.001
Late-term	0.70	0.35	0.24	0.08	0.06	0.05	0.06	0.04	0.01	<0.001
Full-term LBW	1.96	1.71	1.63	1.64	1.65	1.34	1.82	2.01	1.94	0.249
APO	10.25	9.59	9.50	8.90	8.34	8.32	8.84	8.74	8.78	<0.001

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Table 4 (continued)

Variables	Year									*P* value for trend
	2015	2016	2017	2018	2019	2020	2021	2022	2023	
Medical diseases (*n*=66 049)										
Number of deliveries	2 847	5 934	8 090	7 749	8 497	8 402	7 814	8 193	8 523	
Caesarean section rate/%										
<28 weeks	0.00			0.00	50.00	0.00	33.33		0.00	0.584
28−31 weeks	14.29	36.84	44.00	44.00	66.67	47.06	60.00	36.36	50.00	0.176
32−33 weeks	62.50	60.71	44.44	65.38	63.64	56.67	55.56	56.67	48.00	0.521
24−36 weeks	50.00	45.95	55.66	51.18	52.08	58.21	55.49	62.02	55.00	0.018
≤42 weeks	57.14	36.84	22.73	0.00	42.86	33.33	50.00	0.00		0.309
37 and 41^{+6} weeks and body weight <2 500 g	42.42	43.10	41.43	41.43	38.24	35.85	45.71	49.25	58.54	0.031
Adverse birth rate/%										
Extremely preterm	0.04	0.00	0.00	0.04	0.02	0.01	0.04	0.00	0.01	<0.001
Very preterm	0.25	0.32	0.31	0.32	0.21	0.20	0.19	0.13	0.16	0.112
Moderate preterm	0.56	0.47	0.33	0.34	0.26	0.36	0.35	0.37	0.29	<0.001
Late preterm	2.88	2.49	2.62	2.19	2.26	2.39	2.21	2.54	2.35	0.381
Late-term	0.25	0.32	0.27	0.05	0.08	0.07	0.03	0.04	0.00	0.002
Full-term LBW	1.16	0.98	0.87	0.90	0.80	0.63	0.90	0.82	0.96	0.907
APO	5.13	4.58	4.40	3.85	3.64	3.67	3.71	3.89	3.78	<0.001

2.3 Impact of the universal two-child policy on APOs incidence

Using interrupted time series analysis (ITSA), we observed minimal fluctuations in the APO incidence rate during the preimplementation period of the comprehensive two-child policy (January 2015 to June 2016, β<0.001; *P*=0.645; Figure 4A; Supplementary Table 9, https://doi.org/10.57760/sciencedb.xbyxb.00170). Following the implementation of the policy, a significantly steeper upwards trend emerged (β=0.003, *P*<0.001; Figure 4A; Supplementary Table 9). This significant increasing trend in APO incidence persisted even after adjustment for confounding factors during the postpolicy period (β=0.003, *P*<0.001; Figure 4B; Supplementary Table 9).

2.4 Geographical variation in APOs across Hunan prefectures

The incidence of APOs across cities in Hunan Province exhibited relatively minor variation, ranging from 7.09% to 8.53%. Chenzhou in southern Hunan Province recorded the highest provincial rate, at 8.53%, whereas Changde in northern Hunan Province had the lowest at 7.09%. Within western Hunan Province, the Xiangxi Tujia and Miao Autonomous Prefecture reported the lowest incidence (7.13%), whereas Huaihua had the highest (7.92%). In central Hunan Province, Shaoyang demonstrated a relatively high percentage (7.58%), whereas Yiyang and Loudi had identical percentages (7.18%). Xiangtan in eastern Hunan Province emerged as the city with the highest incidence within its region at 8.35%. The APO incidence in the provincial capital, Changsha, which is also located in eastern Hunan Province, was 7.71%. This was marginally higher than the overall provincial average of 7.63% (Figure 5; Supplementary Table 10, https://doi.org/10.57760/sciencedb.xbyxb.00170).

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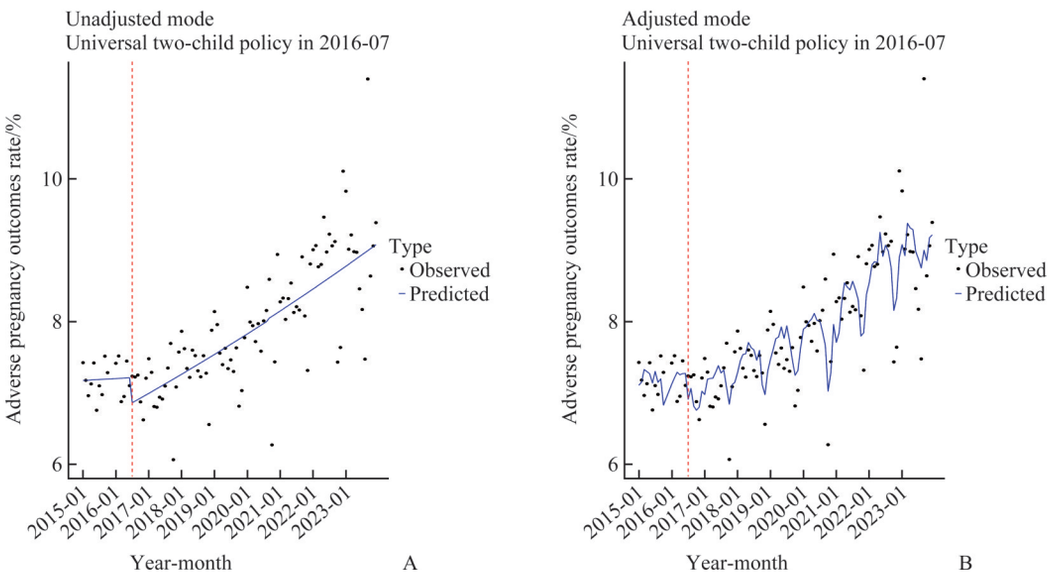


Figure 4 Projected changes in APO incidence among all pregnancies following full implementation of the two-child policy, based on interrupted time series analysis

A: Observed change in APO incidence. B: Change in APO incidence after adjustment for confounding factors. The baseline period spans January 2015 to June 2016. The model was adjusted for advanced maternal age (>35 years) and multiple pregnancy.

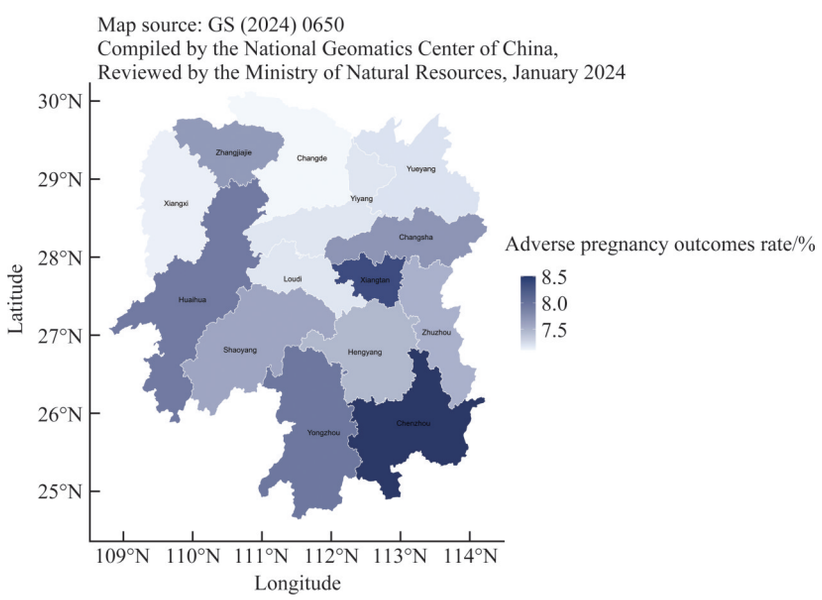


Figure 5 Geographic distribution of cities in Hunan Province and spatial characteristics of APO incidence among women from 2015 to 2023

The map depicts the spatial locations of cities within Hunan Province, with longitude represented on the *X*-axis and latitude on the *Y*-axis. The color gradient indicates the average APO incidence rate (%) across each region over the study period, with lighter shades indicating lower rates and darker shades higher rates.

3 Discussion

This study found that the overall incidence of APOs in Hunan Province increased from 7.18% in 2015 to 9.01% in 2023, representing a 25.37% rise. This increase was primarily driven by preterm births, especially extremely preterm (95.71% increase) and very preterm (48.09% increase) subgroups. The upward

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trend was observed in both singleton and multiple pregnancies, as well as among primiparous and multiparous women. The strongest risk factors associated with APOs were multiple pregnancies (a*OR*= 21.13), advanced maternal age (a*OR*=1.96 for women aged 40−44 years), and caesarean delivery (a*OR*=1.36). Additionally, antepartum complications, medical diseases, and higher hospital level were also significantly associated with increased APO risk, while multiparity and urban residence showed protective effects for certain subgroups.

Globally, the prevalence of APOs is estimated at 10-20%, but accurate rates are hard to determine due to differences in data collection and diagnostic criteria[18]. In 2020, the global preterm birth rate was about 9.9%, while China's was lower at 6.1%[7]. Our study found a 7.63% APO rate in Hunan Province, also below the global average, partly due to healthcare reforms starting in 2009. Hunan implemented targeted reforms, including a 2015 policy for birth defect prevention, establishing comprehensive prevention networks across all life stages. In 2016, public hospital reforms eliminated drug markups and adjusted service prices, reducing medication costs for pregnant women and standardizing clinical practices. By 2023, the birth defect rate in the province dropped from 218.39 per 10 000 live births in 2015 to 163.02, with infant mortality due to birth defects falling below 1.0‰.

However, APOs rates rose for both singleton and multiple pregnancies, mainly due to increased preterm births, especially extremely preterm singletons and very preterm multiples. Similar trends have been noted across China: In Guangzhou, preterm birth rates rose from 5.1% in 2001 to 5.9% in 2016[19]. In Shanghai, LBW rates increased from 2.8% in 2004 to 3.4% in 2020, and preterm births from 4.7% to 5.3%[20]. The association between the universal two-child policy and the rising APO trends is further supported by parity-stratified analyses. Multiparous women, who were directly targeted by the policy, showed a notable increase in APO rates, particularly in very preterm and moderately preterm subgroups. In contrast, the increase in primiparous women was more modest, indicating that the policy-driven demographic shift toward higher parity pregnancies may have amplified the burden of APOs.

The rise in APO rates in Hunan Province is likely due to increased maternal complications, as confirmed by our study and previous research. A national study[21] found higher preterm birth rates among women with gestational diabetes, and another study[22] reported increased preterm births among women with endometriosis. In the Hunan Singleton Pregnancy Cohort, antepartum complications rose nearly sevenfold from 2015 to 2023, and medical diseases increased from 0.94% to 7.55%. These trends suggest that both types of complications significantly contributed to the rise in APO rates.

Maternal age significantly affects APO rates. In Hunan Province, 12.2% of mothers are aged 35 or older, with APO rates rising with age, peaking at 45 and above. This mirrors a Chinese cohort study[23] showing preterm birth rates increasing from 7.6% in women under 35 to 21.6% in those 45 and older. This suggests that the nationwide rise in advanced maternal age pregnancies in China may be partly attributable to a combination of societal factors and the two-child policy.

Multiple pregnancies represent a significant risk factor for APOs. In our study, the incidence of multiple pregnancies in Hunan Province demonstrated a notable increase from 2.34% in 2015 to 3.43% in 2023, a trend that may be attributed to the heightened utilization of assisted reproductive technology (ART) at the national level[9]. These findings are consistent with those reported in other studies[24-25]. Additionally, caesarean delivery was found to be associated with an elevated risk of APOs. Prior studies[26-27] have suggested that primary caesarean delivery may heighten the risk of adverse maternal and neonatal outcomes in subsequent pregnancies. In Hunan Province, the overall rate of caesarean deliveries rose by 25.97% from 2015 to 2023. Specifically, the caesarean rate among multiparous women increased from 40.07% to 48.79% during this timeframe. This association is corroborated by data from other countries, including findings from a Greek cross-sectional study[27-28].

Furthermore, after controlling for confounding variables, our study determined that urban residents exhibited a lower likelihood of preterm birth relative to their rural counterparts. This disparity was predominantly observed in the decreased incidences of late preterm birth, moderate-to-late preterm birth, and

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term low birth weight. Conversely, urban women were found to have an elevated risk of very preterm birth. These differences may be attributable to variations in exposure to heatwaves, maternal education levels, lifestyle factors, and the capacity to identify high-risk pregnancies[29-31].

The implementation of the comprehensive two-child policy on October 29, 2015, likely constituted a significant contextual factor contributing to the rising rates of APOs in Hunan Province. Previous research has demonstrated[9, 12, 32] that subsequent to the policy's enactment, there was an increase in both the proportion of pregnancies among women of advanced maternal age and the incidence of pregnancy complications, thereby elevating the number of established risk factors for APOs. Our findings corroborate this association. During the period in which the policy was in effect, there were notable increases in the proportion of pregnant women aged 35 and older, the proportion of multiparous women, and the rates of antepartum complications, medical conditions, and caesarean deliveries. Our study, focused on the universal two-child policy, is highly relevant to the three-child policy era. The latter encourages more births, likely increasing trends such as advanced maternal age, grand multiparity, and multiple pregnancies from assisted reproductive technology. Consequently, risk factors like advanced maternal age, multiparity, and related complications may become more common. Our findings offer a basis for addressing these challenges under the three-child policy, highlighting the importance of improved preconception counseling, targeted antenatal care for high-order multiparous women, and enhanced neonatal care for preterm and low-birthweight infants.

This study represents the inaugural analysis of the delivery situation in Hunan, China, spanning the years 2015 to 2023. Nonetheless, several limitations are inherent to our research. Firstly, due to the observational design of the study, we can only identify associations between variables rather than establish causality. The link between caesarean delivery and APOs should be interpreted cautiously. Emergency caesareans may result from existing pregnancy complications or fetal distress, rather than causing these outcomes. This reverse causation, where the caesarean is a result of the same issues causing the APOs, is a key limitation of observational cross-sectional studies. Secondly, despite the web-based reporting system encompassing multitiered healthcare facilities throughout Hunan Province, there are concerns regarding potential underreporting of milder cases and variability in diagnostic standards. Thirdly, the simultaneous substantial increase in caesarean rates (a 25.97% rise from 2015 to 2023) and preterm births occurred without distinguishing changes in the proportions of iatrogenic preterm delivery (resulting from planned caesarean sections) versus spontaneous preterm birth, thereby obscuring potential mechanistic differences. Lastly, when compared to data from the eastern and western regions of China, the data from Hunan Province may not be nationally representative due to disparities in healthcare resource allocation, the intensity of policy implementation, and the development of maternal-child health networks.

In summary, this study demonstrates a worrying increase in adverse pregnancy outcomes in Hunan Province from 2015 to 2023, which was accompanied by rising rates of severe preterm births, multiple pregnancies, advanced maternal age, cesarean deliveries, and obstetric complications—trends amplified by the universal two-child policy. Significant geographic and urban-rural disparities further underscore healthcare inequalities. To address this growing burden, targeted strategies such as improved preconception care, enhanced high-risk pregnancy monitoring, strengthened primary healthcare, and optimized surveillance systems are essential. These findings support national maternal and child health goals under "Healthy China 2030" and offer critical insights for policy adaptation amid evolving fertility patterns.

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