

Discordance between abdominal circumference and estimated fetal weight in the late third trimester and risk of adverse perinatal outcomes



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BACKGROUND: Third-trimester fetal ultrasound demonstrating abdominal circumference (AC) and estimated fetal weight (EFW) ≥ 90 th percentile is associated with delivery of a large-for-gestational age (LGA) newborn; however, the clinical significance of discordance between these measures is unclear.

OBJECTIVE: To evaluate the association between discordant AC and EFW percentiles and adverse perinatal outcomes.

STUDY DESIGN: We conducted a retrospective cohort study of singleton pregnancies with a growth ultrasound performed between 32w0d and 36w6d at a single academic center (2017–2024). Fetuses were categorized into four groups based on 90th percentile thresholds for EFW and AC: (1) both < 90 th percentile (reference), (2) isolated large EFW (≥ 90 th, AC < 90 th), (3) isolated large AC (≥ 90 th, EFW < 90 th), and (4) both ≥ 90 th percentile. The primary outcome was LGA birth (birthweight ≥ 90 th by Fenton curve). Secondary outcomes included macrosomia (birthweight ≥ 4000 g), primary cesarean delivery, and shoulder dystocia. Using marginal standardization (parametric G-formula), we estimated adjusted risks, relative risks (aRR), and risk differences controlling for maternal age, body mass index, parity, and diabetes status.

RESULTS: Among 13,592 eligible pregnancies, 75.7% had both EFW and AC < 90 th, 9.7% had isolated large EFW or AC, and 14.6% had both ≥ 90 th percentile. Overall, 12.6% of neonates were LGA. Compared with the reference group, adjusted risk of LGA rose to 17.9% for isolated large AC (aRR 4.3, 95% confidence interval [CI] 3.6–5.1), 21.5% for isolated large EFW (aRR 5.2, 95% CI 4.1–6.5), and 48.2% when both AC and EFW were ≥ 90 th percentile (aRR 11.4, 95% CI 10.2–12.8). Similar stepwise trends were observed for macrosomia, primary cesarean delivery, and shoulder dystocia. Associations were consistent across sensitivity analyses, including stratification by diabetes status.

CONCLUSION: Compared to both AC and EFW < 90 th percentile, isolated third-trimester AC or EFW ≥ 90 th percentile is associated with adverse perinatal outcomes. Patients with an isolated large AC should be counseled regarding these elevated perinatal risks.

Key words: abdominal circumference, cesarean delivery, estimated fetal weight, large-for-gestational age, shoulder dystocia

Introduction

The American College of Obstetricians and Gynecologists (ACOG) recommends at least one standard ultrasound exam, typically between 18 and 22 weeks of gestation, to assess fetal anatomy and estimate gestational age.¹ Third-trimester sonographic measurement of fetal biometry to estimate fetal growth also plays a critical role in modern obstetric care for pregnancies at elevated risk of abnormal fetal growth, guiding clinical decision-making regarding timing and mode of delivery, particularly when abnormal fetal growth is suspected.^{2,3} While universal

third-trimester growth screening is not currently recommended, these evaluations are commonly performed in higher-risk populations, and estimated fetal weight (EFW) and abdominal circumference (AC) are among the most commonly utilized parameters to assess fetal growth. Few studies have examined outcomes when these measurements are discordant.

Fetal macrosomia, traditionally defined as birthweight exceeding 4000 g, affects approximately 7% to 10% of births and is associated with increased risks of cesarean delivery, shoulder dystocia, birth trauma, perineal injuries, postpartum hemorrhage, and neonatal hypoglycemia.⁴ Similarly, large-for-gestational age (LGA) infants, defined as birthweight above the 90th percentile for gestational age, face comparable risks.⁴

Accurate antenatal prediction of macrosomia and LGA remains challenging. Ultrasound-based EFW, calculated using multiple biometric parameters, demonstrates limited sensitivity (approximately 50%–60%) and positive predictive value

(60%–80%) for detecting macrosomia.⁵ AC, primarily reflecting liver size and subcutaneous fat deposition, may be more sensitive for detecting fetal overgrowth, including LGA and macrosomia, particularly in maternal diabetes.^{6–8} When both EFW and AC are at or above the 90th percentile, clinicians commonly counsel patients regarding the risk of delivery complications, including possible primary cesarean section when fetal weight is markedly large and avoidance of operative vaginal delivery to mitigate shoulder dystocia risk.^{2,3,9}

Despite extensive research on fetal growth assessment, the clinical significance of discordance between AC and EFW measurements in the late third trimester remains unclear. Whether an isolated large AC or large EFW carries similar risks as concurrent enlargement is not well understood. Understanding the implications of this discordance could improve risk stratification and reduce unnecessary interventions while ensuring appropriate surveillance for truly high-risk pregnancies.

Cite this article as: Rittenhouse KJ, Johnson JM, Sebastião YV, et al. Discordance between abdominal circumference and estimated fetal weight in the late third trimester and risk of adverse perinatal outcomes. *Am J Obstet Gynecol MFM* 2026;8:102088.

2589-9333/\$36.00

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AJOG MFM at a Glance

Why was this study conducted?

To determine whether discordance between fetal abdominal circumference and estimated fetal weight in late pregnancy is associated with adverse perinatal outcomes.

Key findings

Isolated large abdominal circumference, even with normal estimated fetal weight, was associated with increased risk of large-for-gestational age birth, macrosomia, cesarean delivery, and shoulder dystocia. Risk increased stepwise and was highest when both measures were elevated.

What does this add to what is known?

Abdominal circumference provides independent clinical information beyond estimated fetal weight and may identify high-risk pregnancies otherwise missed by weight-based definitions alone.

The aim of this study was to evaluate the association between discrepant AC and EFW measurements obtained at 32 to 36 weeks' gestation and adverse perinatal outcomes, with particular focus on the risk of LGA, macrosomia, primary cesarean delivery, and shoulder dystocia. Additionally, we assessed whether associations differ among pregnant individuals with and without diabetes mellitus.

Materials and methods**Study design and population**

This retrospective cohort study included patients pregnant with singleton gestations who delivered at the University of North Carolina (UNC) Hospitals and underwent an ultrasound at a UNC antenatal clinic between November 2017 and November 2024. At UNC, third-trimester growth ultrasounds are performed for pregnant individuals with risk factors for abnormal fetal growth (eg, diabetes, hypertensive disorders of pregnancy) or a fundal height discrepancy of greater than 2 centimeters from expected. Universal third-trimester growth surveillance is not performed for low-risk patients. From this population, we identified those with a growth ultrasound performed between 32⁰/₇ and 36⁶/₇ weeks. If a patient had more than one eligible ultrasound in the study window, only the first examination was included. Exclusion criteria were multifetal gestations (twins or higher-order multiples),

pregnancies with fetal structural anomalies or chromosomal/genetic abnormalities identified using ICD-10 diagnosis codes, missing AC or EFW measurements, or missing data on birthweight or newborn sex. Analyses were conducted as a complete case analysis. Fewer than 5% of otherwise eligible pregnancies were excluded due to missing exposure, outcome, or covariate data. Given the low proportion of missingness and the absence of systemic patterns of missing data across key exposure groups, we expected minimal bias from this exclusion. For outcomes derived from the electronic medical record (EMR), absence of a documented diagnosis was assumed to indicate absence of the exposure or outcome. This study was approved by the UNC-Chapel Hill Office of Human Research Ethics.

Except for participants who had conceived by in vitro fertilization (IVF), the gestational age was determined by the best obstetric estimate using the first ultrasound demonstrating a viable intrauterine pregnancy in combination with last menstrual period (if known in patient with regular menstrual cycles), according to ACOG guidelines.¹⁰ Gestational age for IVF pregnancies was established by date of embryo transfer, confirmed by first-trimester ultrasound. EFW was estimated using Hadlock IV four-parameter (biparietal diameter [BPD], head circumference [HC], AC, femur length [FL]) formula.¹¹ EFW and

AC percentiles were estimated using Hadlock reference standards.¹²

Sonography

All ultrasounds were performed by experienced, certified obstetric sonographers at UNC antenatal clinics using GE ultrasound machines (GE Healthcare, Zipf, Austria) approved by the US Food and Drug Administration for fetal imaging. All imaging studies were interpreted by board-certified Maternal-Fetal Medicine physicians with expertise in prenatal diagnosis. Biometry measurements included BPD, HC, AC, and FL. Each structure was measured at least twice, with the average used in biometry calculations. Fetal views were obtained and measurement calipers placed per ISUOG guidelines.¹³

Exposure and outcome variables

For each pregnancy, we abstracted general demographic, clinical information, and pregnancy-related diagnoses from UNC's EMR using ICD-10 diagnosis codes for clinical diagnoses (eg, diabetes); delivery outcomes (eg, cesarean delivery, shoulder dystocia, Apgar scores) were extracted from structured fields in the EMR delivery summary; and ultrasound biometry was extracted from structured sonographic reports. The exposures of interest were (1) AC ≥ 90 th percentile and (2) EFW ≥ 90 th percentile. The primary outcome of interest was LGA birth, defined as birthweight ≥ 90 th percentile for gestational age by the Fenton curve.¹⁴ Secondary outcomes included macrosomia (birthweight ≥ 4000 g), primary cesarean delivery, and shoulder dystocia. Additional obstetric and neonatal outcomes (polyhydramnios, NICU admission, stillbirth, and Apgar < 5 at 5 minutes) were examined descriptively. Polyhydramnios was defined as amniotic fluid index ≥ 24.0 cm or deepest vertical pocket ≥ 8 cm.¹⁵ as documented on the ultrasound report. Stillbirth was defined as fetal demise at ≥ 20 weeks' gestation, as documented in the delivery summary or obstetric history of the EMR.¹⁶

Statistical analyses

We summarized maternal characteristics and delivery outcomes across four fetal growth categories defined by the 90th percentile threshold for EFW and AC: (1) EFW <90th percentile, AC <90th percentile (reference group); (2) EFW ≥90th percentile, AC <90th percentile; (3) EFW <90th percentile, AC ≥90th percentile; and (4) EFW ≥90th percentile, AC ≥90th percentile. Continuous variables were reported as medians with interquartile ranges (IQRs), and categorical variables as frequencies with percentages.

For each outcome, we calculated risk, relative risk (RR), and risk difference (RD), as well as adjusted risk, adjusted RR (aRR), and adjusted RD (aRD) with corresponding 95% confidence intervals (CIs). We used the marginal standardization approach to obtain unadjusted and adjusted risk estimates. This was implemented for each outcome in Stata/SE 18.0 in two steps. First, we fit a logistic regression model of the outcome with binary (yes; no) exposure variables for (1) EFW ≥90th percentile, AC <90th percentile; (2) EFW <90th percentile, AC ≥90th percentile; and (3) EFW ≥90th percentile, AC ≥90th percentile, along with prespecified maternal covariates, or no covariates for unadjusted models. Second, we ran the *adjrr* command—wrapper that calls on other Stata commands to obtain (1) the population-averaged risks of outcome associated with each exposure category (predictive margins; from *margins* command), (2) the RD (linear combination of predictive margins; from *lincom* command), (3) the risk ratio (nonlinear combination of margins; *nlcom* command), and (4) their delta-method robust standard errors.¹⁷ This approach provides outcome risks and contrasts between exposure groups that are standardized to the population distribution of covariates, thereby removing confounding by these covariates. For all outcomes, we included the following covariates for adjustment: age at conception and body mass index (BMI), both modeled as continuous variables, as well as parity and diabetes (pregestational or gestational). BMI was

calculated using the first weight recorded in pregnancy or, if unavailable, the closest weight preceding pregnancy within 1 year. Covariates were selected a priori for clinical significance and a directed acyclic graph framework to identify the minimally sufficient adjustment set for confounding control. Primary-cesarean analyses were restricted to pregnant individuals without prior cesarean; shoulder dystocia analyses were limited to vaginal, cephalic deliveries.

We conducted four sensitivity analyses to assess the robustness of our findings. First, we stratified all models by diabetes status (pregestational or gestational vs no diabetes) to evaluate whether associations between fetal growth patterns and outcomes differed by this maternal metabolic condition. Second, we restricted the cohort to narrower gestational age windows at ultrasound (32⁰–33⁶ weeks and 34⁰–36⁶ weeks) to assess whether the timing of the growth ultrasound influenced the observed outcomes. Third, among pregnant individuals with more than one eligible pregnancy during the study period, we randomly retained one pregnancy to avoid potential clustering or overrepresentation of individuals with multiple deliveries. Fourth, we repeated analyses after excluding preterm deliveries (<37⁰ weeks) to examine the associations within the term population, where size-related complications are most mechanistically linked to delivery outcomes. Because only 12.1% (1650/13,592) of the cohort delivered preterm, we anticipated minimal selection bias from this restriction; nonetheless, conditioning on term delivery can introduce bias if preterm birth risk differs by exposure or unmeasured factors, so these results should be interpreted cautiously. Analyses were conducted using Stata/SE 18.0 (StataCorp, College Station, TX).

Results

Study population

Between November 2017 and November 2024, a total of 13,592 singleton pregnancies met inclusion criteria (Figure). Of these, 75.7% had both EFW

and AC <90th percentile (reference group), 2.6% had an isolated large EFW (≥90th with AC <90th), 7.1% had an isolated large AC (≥90th with EFW <90th), and 14.6% had both EFW and AC ≥90th percentile (Table 1).

Median maternal age was 31 years (IQR 26–35), and median BMI was 30 kg/m² (IQR 25–37). Pregnant individuals with large EFW and/or AC were more likely to have obesity and diabetes, with median BMI increasing from 30 kg/m² in the reference group to 33 kg/m² in those with both parameters ≥90th percentile. The prevalence of diabetes rose from 21.2% in the reference group to 39.2% in the combined large EFW/AC group, reflecting both pregestational and gestational diabetes contributions. Chronic hypertension was also more frequent among pregnancies with large fetal biometry, while nulliparity was less common.

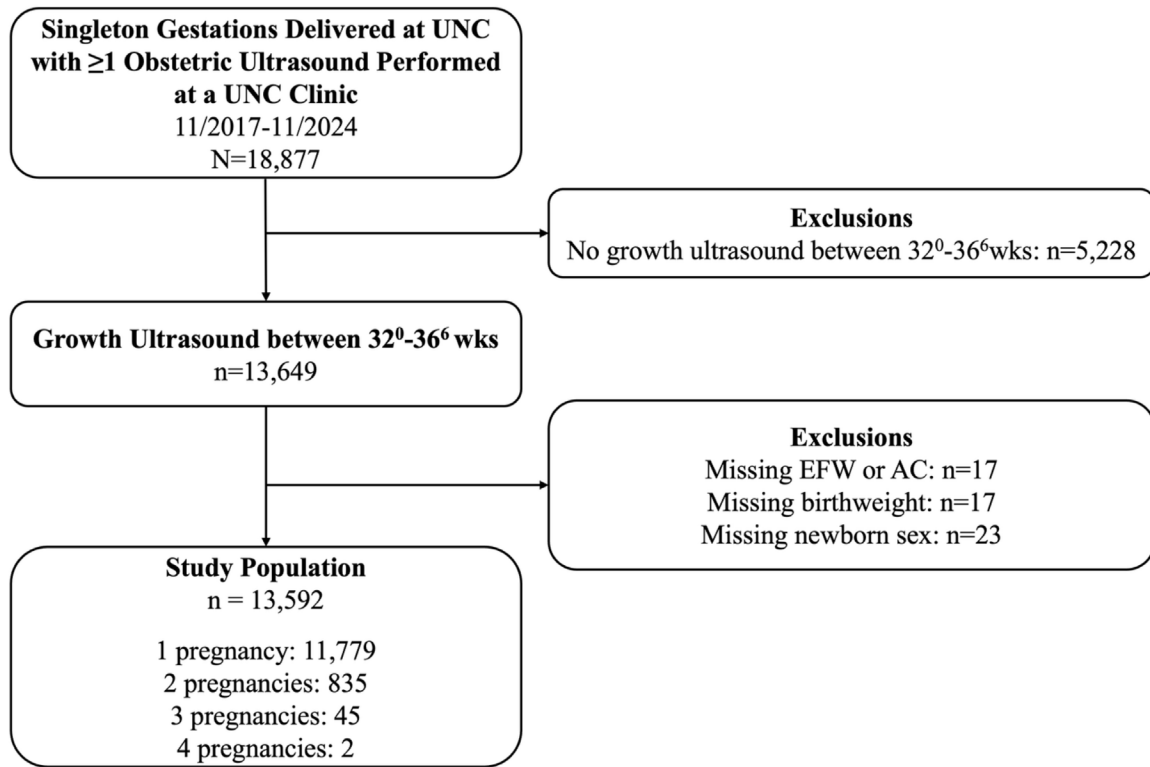
Delivery outcomes

Median gestational age at delivery was 38⁶ weeks (IQR 37³–39⁴). Birthweight increased progressively across fetal biometry strata, from a median of 3090 g (IQR 2734–3405) in the reference group to 3760 g (IQR 3453–4069) among fetuses with both EFW and AC ≥90th percentile (Table 2). The prevalence of LGA increased from 4.3% in the reference group to 50.6% in the combined large EFW/AC group. Similarly, birthweight ≥4000 g occurred in 7.0% of pregnancies overall, increasing with large EFW and AC percentile groups.

Polyhydramnios was observed in 5.8% of pregnancies and was most frequent among those with both large EFW and AC (16.6%). Cesarean delivery occurred in 36.2% of the cohort, increasing from 33.7% in the reference group to 47.1% in the combined large group. Among pregnant individuals without a prior cesarean, the primary cesarean rate rose from 28.9% to 41.5% across the same groups. Shoulder dystocia also increased among larger biometry groups, rising from 1.1% in the reference group to 5.9% among fetuses with both large EFW and AC.

FIGURE

Study population flow diagram



Flow of participants included in the analysis of singleton pregnancies delivered at UNC Hospitals with at least one obstetric ultrasound performed at a UNC clinic (2017–2024). The analytic cohort was restricted to pregnancies with a growth ultrasound performed between 32⁰ and 36⁶ weeks' gestation. Pregnancies were excluded for multifetal gestation, genetic and structural anomalies, missing biometric data (AC or EFW), or missing delivery outcome data (birthweight or newborn sex).

Rittenhouse. Discordance between abdominal circumference and estimated fetal weight. *Am J Obstet Gynecol MFM* 2026.

Severe neonatal morbidity was uncommon. Stillbirth was rare (0.1%). A 5-minute Apgar <5 occurred in 1.6% of births, and NICU admission occurred in 13.6% of births, increasing to 17.6% among those with both large EFW and AC.

Large-for-gestational age

Overall, 12.6% of infants were LGA at birth. Compared to the reference group (Table 3; adjusted risk 4.1%), the adjusted risk of LGA increased markedly across fetal biometry strata: 21.5% for isolated large EFW (aRR 5.2, 95% CI 4.1–6.5), 17.9% for isolated large AC (aRR 4.3, 95% CI 3.6–5.1), and 48.2% for those with both EFW and AC ≥90th percentile (aRR 11.4, 95% CI 10.2–12.8). The corresponding aRDs were 17.3% (95% CI 12.9

–21.8), 13.8% (95% CI 11.1–16.3), and 44.0% (95% CI 41.6–46.5), respectively.

Macrosomia

The prevalence of macrosomia (birthweight ≥4000 g) was 7.0% overall, with increasing adjusted risk from 2.2% in the reference group to 29.1% among fetuses with both EFW and AC ≥90th percentile (Table 4). The aRR of macrosomia was 5.4 for isolated large EFW (95% CI 3.9–7.5), 4.1 for isolated large AC (95% CI 3.2–5.4), and 13.2 when both parameters were ≥90th percentile (95% CI 11.2–15.4). These corresponded to aRDs ranging from 6.9% for isolated large AC to 26.8% for combined large EFW and AC.

Primary cesarean delivery

Among pregnant individuals without a prior cesarean, the adjusted risk of primary cesarean delivery was 28.0% in the reference group, 34.6% with isolated large EFW, 31.2% with isolated large AC, and 38.8% with both parameters ≥90th percentile. The aRR ranged from 1.1 (95% CI 1.0–1.2) for isolated large AC to 1.4 (95% CI 1.3–1.5) for combined large EFW and AC, reflecting an aRD of 10.8% in the combined large biometry group.

Shoulder dystocia

The adjusted risk of shoulder dystocia was 1.1% of vaginal deliveries in the reference group, rising to 2.2% with isolated large EFW, 3.0% with isolated large AC, and 5.9% when

TABLE 1
Maternal characteristics by EFW and AC percentile groups

Maternal characteristic	Total <i>n</i> (%) median (IQR)	EFW<90%, AC<90% <i>n</i> (%) median (IQR)	EFW≥90%, AC<90% <i>n</i> (%) median (IQR)	EFW<90%, AC≥90% <i>n</i> (%) median (IQR)	EFW≥90%, AC≥90% <i>n</i> (%) median (IQR)
Pregnancies, <i>n</i> (%)	13,592	10,285 (75.7%)	350 (2.6%)	968 (7.1%)	1989 (14.6%)
Race					
White	6156 (45.4%)	4438 (43.2%)	191 (54.6%)	475 (49.2%)	1052 (52.9%)
Black/African American	3337 (24.6%)	2782 (27.1%)	79 (22.6%)	144 (14.9%)	332 (16.7%)
Other ^a	837 (6.2%)	720 (7.0%)	16 (4.6%)	33 (3.4%)	68 (3.4%)
Unknown	3245 (23.9%)	2333 (22.7%)	64 (18.3%)	313 (32.4%)	535 (26.9%)
Ethnicity					
Not Hispanic/Latino	10,228 (75.3%)	7874 (76.6%)	280 (80.0%)	651 (67.3%)	1423 (71.5%)
Hispanic/Latino	3011 (22.2%)	2144 (20.9%)	61 (17.4%)	289 (29.9%)	517 (26.0%)
Unknown	353 (2.6%)	267 (2.6%)	9 (2.6%)	28 (2.9%)	49 (2.5%)
Maternal age (y)	31 (26, 35)	30 (26, 35)	31 (26, 35)	31 (26, 35)	32 (28, 36)
Parity	1 (0, 2)	1 (0, 2)	1 (0, 2)	1 (0, 2)	1 (0, 2)
Nulliparous	5132 (37.8%)	4140 (40.3%)	133 (38.0%)	321 (33.2%)	538 (27.0%)
IVF conception	294 (2.2%)	206 (2.0%)	7 (2.0%)	17 (1.8%)	64 (3.2%)
BMI (kg/m ²)	30 (25, 37)	30 (24, 36)	33 (27, 39)	31 (26, 38)	33 (27, 40)
Any diabetes	3389 (24.9%)	2179 (21.2%)	104 (29.7%)	327 (33.8%)	779 (39.2%)
Pregestational diabetes	1358 (10.0%)	801 (7.8%)	32 (9.1%)	142 (14.7%)	383 (19.3%)
Gestational diabetes	2031 (14.9%)	1378 (13.4%)	72 (20.6%)	185 (19.1%)	396 (19.9%)
Chronic hypertension	2627 (19.3%)	1894 (18.4%)	83 (23.7%)	206 (21.3%)	444 (22.3%)
Illicit drug use	687 (5.1%)	576 (5.6%)	6 (1.7%)	38 (3.9%)	67 (3.4%)
Tobacco use	789 (5.8%)	667 (6.5%)	5 (1.4%)	51 (5.3%)	75 (3.8%)
Autoimmune disease	1120 (8.2%)	800 (7.8%)	35 (10.0%)	82 (8.5%)	203 (10.2%)
Prior cesarean	1766 (20.9%)	1242 (20.2%)	49 (22.6%)	151 (23.3%)	324 (22.3%)

Illicit drug use and tobacco use were recorded if reported during pregnancy. Prior cesarean delivery was assessed only among parous individuals (nulliparous individuals excluded).

IVF, in vitro fertilization.

^a Other includes American Indian/Alaska Native, Asian, Native Hawaiian/Pacific Islander, Middle Eastern/North African.

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both EFW and AC were ≥90th percentile. The combined high group demonstrated the greatest risk (aRR 5.6, 95% CI 3.9–8.1; aRD 4.9%, 95% CI 3.3–6.5).

Sensitivity analyses

Findings were consistent across sensitivity analyses. When stratified by diabetes status, associations between large fetal biometry and adverse outcomes were observed in both diabetic and non-diabetic pregnancies, with higher absolute risks among those with diabetes but similar relative effect sizes

(Supplemental Tables 1 and 2). Results were similar when restricting analyses to narrower gestational age windows at ultrasound (Supplemental Tables 3 and 4), and when retaining one random pregnancy per individual (Supplemental Tables 5 and 6). When restricting analyses to term deliveries (Supplemental Tables 7 and 8), estimates were directionally consistent with the main analyses and of similar magnitude. As only 12.1% of the cohort delivered preterm, selection bias from this restriction is likely limited; however, we acknowledge that excluding preterm births could

differentially affect exposure groups. These consistent findings across strata support that the associations between large AC and EFW and adverse perinatal outcomes are not explained by effect-measure modification.

Structured discussion/ comment

Principal findings

In this large contemporary cohort of over 13,000 singleton pregnancies, both EFW and AC ≥90th percentiles in the late third trimester are associated with adverse perinatal outcomes.

TABLE 2

Delivery outcomes by EFW and AC percentile groups

Outcomes	Total <i>n</i> (%) median (IQR)	EFW <90%, AC <90% <i>n</i> (%) median (IQR)	EFW ≥90%, AC <90% <i>n</i> (%) median (IQR)	EFW <90%, AC ≥90% <i>n</i> (%) median (IQR)	EFW ≥90%, AC ≥90% <i>n</i> (%) median (IQR)
Pregnancies, <i>n</i> (%)	13,592	10,285 (75.7%)	350 (2.6%)	968 (7.1%)	1989 (14.6%)
Labor induction	7425 (54.7%)	5706 (55.6%)	201 (57.4%)	513 (53.2%)	1005 (50.6%)
Polyhydramnios ^a	793 (5.8%)	353 (3.4%)	28 (8.0%)	81 (8.4%)	331 (16.6%)
GA at delivery (wk)	38 ⁶ (37 ³ –39 ³)	39 ⁰ (37 ³ –39 ⁴)	39 ⁰ (37 ⁶ –39 ³)	39 ⁰ (37 ² –39 ³)	38 ⁴ (37 ² –39 ²)
Newborn sex					
Male	6880 (50.6%)	5027 (48.9%)	208 (59.4%)	516 (53.3%)	1129 (56.8%)
Female	6712 (49.4%)	5258 (51.1%)	142 (40.6%)	452 (46.7%)	860 (43.2%)
Stillbirth	19 (0.1%)	17 (0.2%)	1 (0.3%)	1 (0.1%)	0 (0.0%)
LGA (BW >90th percentile)	1708 (12.6%)	438 (4.3%)	76 (21.7%)	187 (19.3%)	1007 (50.6%)
Birthweight (g)	3220 (2850, 3570)	3090 (2734, 3405)	3553 (3270, 3815)	3463 (3190, 3753)	3760 (3453, 4069)
≥4000 g	947 (7.0%)	224 (2.2%)	42 (12.0%)	92 (9.5%)	589 (29.6%)
≥4500 g	142 (1.0%)	10 (0.1%)	4 (1.1%)	8 (0.8%)	120 (6.0%)
≥5000 g	18 (0.1%)	1 (0.0%)	0 (0.0%)	1 (0.1%)	16 (0.8%)
5 min APGAR <5	219 (1.6%)	165 (1.6%)	7 (2.0%)	17 (1.8%)	30 (1.5%)
NICU admission	1845 (13.6%)	1350 (13.1%)	35 (10.0%)	110 (11.4%)	350 (17.6%)
NICU admission ≥48 h	1253 (9.2%)	936 (9.1%)	22 (6.3%)	69 (7.1%)	226 (11.4%)
Cesarean delivery	4926 (36.2%)	3467 (33.7%)	152 (43.4%)	371 (38.3%)	936 (47.1%)
Primary cesarean ^b	3657 (31.1%)	2596 (28.9%)	111 (37.3%)	263 (32.4%)	687 (41.5%)
Malpresentation	454 (3.9%)	350 (3.9%)	14 (4.7%)	23 (2.8%)	67 (4.0%)
Arrest disorder ^c	800 (6.8%)	518 (5.8%)	31 (10.4%)	74 (9.1%)	177 (10.7%)
Suspected macrosomia	64 (0.5%)	5 (0.1%)	2 (0.7%)	3 (0.4%)	54 (3.3%)
Fetal intolerance	725 (6.2%)	571 (6.4%)	20 (6.7%)	51 (6.3%)	83 (5.0%)
Shoulder dystocia ^d	160/8666 (1.8%)	74/6818 (1.1%)	4/198 (2.0%)	20/597 (3.4%)	62/1053 (5.9%)

BW, birthweight; LGA, large for gestational age.

^a Polyhydramnios was defined as a deepest vertical pocket (DVP) ≥8 cm or amniotic fluid index (AFI) ≥24 cm; ^b Primary cesarean delivery excludes patients with a prior cesarean delivery; ^c Arrest disorder includes failed induction of labor, arrest of dilation, and arrest of descent; ^d Shoulder dystocia rates were calculated among cephalic vaginal deliveries only.

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We found that an isolated large AC was relatively common and independently associated with increased risks of LGA, macrosomia, primary cesarean delivery, and shoulder dystocia. The magnitude of these associations was comparable to that observed for isolated large EFW, and outcomes were most pronounced when both parameters were ≥90th percentile. These data suggest that an enlarged fetal abdomen, even in the absence of overall fetal overgrowth, identifies a subset of pregnancies at elevated risk for delivery complications traditionally attributed to macrosomia.

Results

Our findings add to a growing body of evidence that discordance among biometric parameters provides important clinical information beyond composite EFW alone.^{18,19} These results are consistent with a meta-analysis of 40 studies,²⁰ which found that AC alone performed comparably to composite EFW for predicting LGA birth, with AC-based cutoffs demonstrating similar or, in some analyses, superior sensitivity and specificity relative to EFW thresholds. Our findings extend this work by demonstrating that isolated AC elevation, independent of EFW, is associated

not only with LGA but with a broader spectrum of adverse perinatal outcomes, including macrosomia, primary cesarean delivery, and shoulder dystocia, in a contemporary cohort using adjusted risk-based methods. Although EFW remains central to fetal growth assessment, AC reflects soft tissue and hepatic glycogen stores and may serve as an early marker of fetal overnutrition and insulin-mediated growth.^{6,8,21,22} particularly in the setting of maternal diabetes or obesity.^{23,24} In our cohort, an isolated large AC was more prevalent than an isolated large EFW and conferred comparable risk for LGA birth and

TABLE 3
Unadjusted and adjusted association between LGA birth and EFW and AC percentile groups

Exposure	Total, n (%)	Risk, % (95% CI)	Adjusted risk, % (95% CI)	Relative risk (95% CI)	Adjusted relative risk (95% CI)	Risk difference (95% CI)	Adjusted risk difference (95% CI)
EFW < 90%, AC < 90%	10 285 (75.7%)	4.3 (3.9, 4.7)	4.1 (3.7, 4.5)	1.00 (reference)	1.00 (reference)	0.0 (reference)	0.0 (reference)
EFW ≥ 90%, AC < 90%	350 (2.6%)	21.7 (17.7, 26.3)	21.5 (17.0, 25.9)	5.1 (4.1, 6.3)	5.2 (4.1, 6.5)	17.5 (13.1, 21.8)	17.3 (12.9, 21.8)
EFW < 90%, AC ≥ 90%	968 (7.1%)	19.3 (17.0, 22.0)	17.9 (15.4, 20.5)	4.5 (3.9, 5.3)	4.3 (3.6, 5.1)	15.1 (12.5, 17.6)	13.8 (11.1, 16.3)
EFW ≥ 90%, AC ≥ 90%	1989 (14.6%)	50.6 (48.4, 52.8)	48.2 (45.8, 50.6)	11.9 (10.7, 13.2)	11.4 (10.2, 12.8)	46.4 (44.1, 48.6)	44.0 (41.6, 46.5)

Risk, relative risk, and risk differences were estimated using model-based marginal standardization. Adjusted models standardized for maternal age, BMI, parity, and diabetes.

AC, abdominal circumference; CI, confidence interval; EFW, estimated fetal weight; LGA, large-for-gestational age.

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macrosomia. This suggests that enlargement of the fetal abdomen may precede or occur independently of increases in overall fetal weight. Prior studies have similarly linked disproportionate abdominal growth with excessive birthweight and shoulder dystocia, even when EFW is normal.²⁵ Our findings reinforce that AC should not be interpreted merely as one of several components contributing to EFW, but rather as a distinct indicator of metabolic and delivery risk.

Stepwise increases in cesarean delivery and shoulder dystocia across fetal biometry categories are consistent with prior reports linking larger fetuses with mechanical labor complications.²⁶ Importantly, our data show that the risk of primary cesarean and shoulder dystocia was elevated not only among fetuses with large EFW but also among those with large AC alone.

These findings should be interpreted in light of differences in study populations and reference standards. Unlike cohorts restricted to diabetic pregnancies,^{19,27} or unselected general-obstetric populations, ours comprised patients undergoing clinically indicated third-trimester growth ultrasonography at a tertiary center, limiting direct numerical comparison with lower-risk populations. Reference standards also differ: we applied Hadlock biometric percentiles and the Fenton birthweight curve, whereas prior studies have variably used INTERGROWTH-21st, WHO, or customized charts, which reclassify a meaningful proportion of fetuses between appropriate and LGA and thereby shift both LGA prevalence and apparent risk.²⁸ Nonetheless, our results are directionally concordant with prior work, our overall macrosomia rate (7.0%) falls within the commonly reported range,⁴ supporting AC as an independent marker of delivery risk across differing populations and standards.

Clinical implications

These findings have practical implications for clinical risk stratification and counseling. Current guidelines^{2,3} define “suspected macrosomia” using

thresholds based on EFW rather than individual biometric components. Our results suggest that relying solely on EFW to identify pregnancies at risk for macrosomia-related complications may miss a clinically meaningful subset of fetuses with excessive abdominal growth.

The physiologic and pathophysiologic mechanisms underlying isolated enlargement of the fetal abdomen may differ from those driving overall fetal overgrowth. AC enlargement may reflect altered glucose metabolism, placental nutrient transfer, or early fetal adiposity.^{23,29,30} Associations between isolated large AC and outcomes were similar in pregnant individuals with and without diabetes, suggesting the relationship between AC and risk is not entirely mediated by maternal glycemia. This aligns with evidence that fetal fat deposition and hepatic growth may represent the final common pathway of multiple metabolic and placental processes leading to excess fetal size.^{7,21,22}

The detection of an isolated large AC raises management questions regarding the timing and mode of delivery. While our study was not designed to assess the benefits of intervention, the observed risk gradient across biometry categories suggests that large AC, even with normal EFW, may warrant closer surveillance, anticipatory counseling regarding labor progress, and preparedness for shoulder dystocia. However, these findings should be interpreted within the broader context of the modest absolute risks and the well-documented inaccuracy of third-trimester ultrasound in estimating fetal size.^{31–33} The potential for false-positive labeling of “large” fetuses underscores the importance of individualized decision-making. A central question these findings raise is whether earlier delivery should be considered for an isolated large AC. The randomized evidence is indirect: induction for suspected overgrowth reduces shoulder dystocia and birth injury but has not been shown to reduce cesarean delivery.^{34,35} and a recent trial, which used a ≥90th percentile EFW threshold, showed a significant reduction in

TABLE 4

Adjusted association between EFW and AC percentile groups and the risks of macrosomia, primary cesarean delivery, and shoulder dystocia

Exposure	Macrosomia (birthweight ≥4000 g)				Primary cesarean delivery				Shoulder dystocia			
	Total, n (%)	Adjusted risk (95% CI)	Adjusted relative risk (95% CI)	Adjusted risk difference (95% CI)	Total, n (%)	Adjusted risk (95% CI)	Adjusted relative risk (95% CI)	Adjusted risk difference (95% CI)	Total, n (%)	Adjusted risk (95% CI)	Adjusted relative risk (95% CI)	Adjusted risk difference (95% CI)
EFW<90%, AC<90%	10,285 (75.7%)	2.2 (1.9, 2.5)	1.00 (reference)	0.0 (reference)	8810 (76.7%)	28.0 (27.0, 28.9)	1.00 (reference)	0.0 (reference)	6818 (78.7%)	1.1 (0.8, 1.3)	1.00 (reference)	0.0 (reference)
EFW≥90%, AC<90%	350 (2.6%)	11.8 (8.2, 15.4)	5.4 (3.9, 7.5)	9.6 (5.0, 13.2)	295 (2.6%)	34.6 (29.1, 40.2)	1.2 (1.1, 1.5)	2.9 (1.1, 12.3)	198 (2.3%)	2.2 (0.1, 4.2)	2.0 (0.7, 5.5)	1.1 (−1.0, 3.2)
EFW<90%, AC≥90%	968 (7.1%)	9.1 (7.1, 11.1)	4.1 (3.2, 5.4)	6.9 (4.9, 8.9)	796 (6.9%)	31.2 (27.8, 34.5)	1.1 (1.0, 1.2)	3.2 (0.0, 6.7)	597 (6.9%)	3.0 (1.5, 4.5)	2.8 (1.6, 4.9)	2.0 (0.5, 3.5)
EFW≥90%, AC≥90%	1989 (14.6%)	29.1 (26.8, 31.3)	13.2 (11.2, 15.4)	26.8 (24.6, 29.1)	1592 (13.9%)	38.8 (36.3, 41.3)	1.4 (1.3, 1.5)	10.8 (8.1, 13.5)	1053 (12.2%)	5.9 (4.4, 7.5)	5.6 (3.9, 8.1)	4.9 (3.3, 6.5)

Risk, relative risk, and risk differences were estimated using model-based marginal standardization. Adjusted models standardized for maternal age, BMI, parity, and diabetes. Primary cesarean delivery modeling excludes individuals with a prior cesarean delivery. Shoulder dystocia modeling includes cephalic vaginal deliveries only.

AC, abdominal circumference; CI, confidence interval; EFW, estimated fetal weight.

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shoulder dystocia only on per-protocol analysis.³⁶ Crucially, every such trial enrolled by EFW-based criteria; a fetus with an isolated large AC would generally not have qualified, and no trial has tested AC-based delivery timing. Whether this group benefits from delivery at or before 39 weeks therefore remains unanswered and warrants prospective study incorporating AC into eligibility.

These findings should not be directly applied to counseling patients with a prior cesarean delivery, as the primary cesarean analysis was restricted to patients without a prior cesarean and this study did not evaluate trial of labor after cesarean (TOLAC) outcomes. Whether discordant AC/EFW patterns influence vaginal birth after cesarean success, uterine rupture risk, or other TOLAC-related outcomes requires dedicated investigation.

Research implications

Prospective studies are needed to determine whether incorporating AC or discordant biometry into prediction models improves outcomes. Recent studies incorporating AC z-scores or growth velocity into composite prediction models have shown improved discrimination for LGA birth compared with EFW alone.^{18,27,37} Integration of discordant biometry patterns—particularly large AC with normal head or femur measurements—into predictive algorithms could further enhance their performance. Future analyses should evaluate whether continuous measures of biometric discordance, such as AC-to-EFW ratios, AC z-scores, or z-score differences between AC and other biometric parameters, improve prediction of LGA birth and delivery complications beyond the categorical percentile thresholds used in this analysis.

Strengths and limitations

This study has several strengths. It represents one of the largest single-center analyses to date examining discordant fetal biometry and its relationship with delivery outcomes. The availability of detailed ultrasound and delivery data allowed for rigorous adjustment for

confounders, including maternal diabetes, BMI, and parity. Consistency of findings across multiple sensitivity analyses—including stratification by diabetes status, gestational age at scan, and restriction to term and singleton pregnancies—supports the internal validity of our results.

Nevertheless, certain limitations merit consideration. Large AC and EFW may be best understood as markers of excess fetal growth, and this analysis describes associations rather than mechanisms. Residual confounding by unmeasured factors such as maternal metabolic health, gestational weight gain, or clinical management practices may persist but is unlikely to fully explain the observed associations; incomplete capture of early-pregnancy weights, particularly among patients receiving shared care with community obstetric practices, limits our ability to calculate gestational weight gain reliably. Relatedly, we did not adjust for induction of labor, as it occurs after the exposure and lies on the causal pathway to cesarean delivery, including inductions scheduled specifically for macrosomia, such that adjustment would represent overadjustment for a mediator; our estimates therefore reflect the total effect of fetal biometry, inclusive of induction-mediated pathways. We also did not adjust for maternal race or ethnicity. We regard these as social rather than biological constructs that are not themselves causes of fetal growth but may proxy for structural and social determinants of perinatal risk that we could not directly measure.³⁸ Adjusting for them as confounders, absent measures of those upstream factors, risks obscuring rather than clarifying disparities and implying a biological interpretation we do not endorse. Self-reported race and ethnicity were also variably documented in our record.

Several features of our data and design also affect interpretation. Because inclusion required survival and ultrasound after 32 weeks, pregnancies delivering earlier may be underrepresented, introducing potential selection bias. Ultrasound measurement error and interobserver

variability could contribute to nondifferential misclassification, likely biasing estimates toward the null. The study population reflects a higher-risk group—patients undergoing clinically indicated third-trimester growth ultrasounds at a tertiary academic center—and findings may not be generalizable to unselected low-risk pregnancies for whom routine third-trimester growth surveillance is not currently recommended. Our exposure definitions used a ≥ 90 th percentile threshold for both EFW and AC; therefore, findings may not be directly generalizable to centers that use alternative thresholds, such as the ≥ 95 th percentile cutoff used in some European settings.^{34,39} A ≥ 95 th percentile threshold would identify a smaller subgroup with more severe overgrowth and may be associated with different absolute and RRs. The observed preterm birth rate of 12.1% likely reflects the clinically indicated nature of third-trimester growth ultrasound surveillance at a high-risk academic referral center, with enrichment for diabetes, hypertensive disorders, and other conditions associated with indicated preterm delivery. Findings were directionally consistent in sensitivity analyses restricted to term deliveries. Finally, while we examined key clinical outcomes, we did not assess perineal lacerations, postpartum hemorrhage, neonatal birth injury, maternal morbidity, neonatal metabolic measures, or long-term outcomes, which could further clarify the biological and clinical significance of isolated large AC.

Conclusions

In summary, both large EFW and large AC in the late third trimester are strongly associated with LGA birth and delivery complications, with similar magnitude of risk when either parameter is large in isolation. These findings indicate that an enlarged fetal abdomen identifies pregnancies at increased risk for macrosomia-related complications, even in the absence of overall fetal overgrowth. Incorporating AC thresholds into fetal growth assessment and risk

counseling may improve identification of at-risk pregnancies and inform management strategies aimed at optimizing perinatal outcomes. Future studies should evaluate whether AC-based or discordance-aware growth definitions enhance prediction and clinical decision-making beyond current EFW-based thresholds. ■

CRedit authorship contribution statement

Katelyn J. Rittenhouse: Writing – review & editing, Writing – original draft, Project administration, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Julie M. Johnson:** Writing – review & editing, Supervision, Methodology, Investigation, Conceptualization. **Yuri V. Sebastião:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis, Conceptualization. **Nicole M. Davis:** Writing – review & editing, Methodology, Data curation. **Rebecca L. Ritter:** Writing – review & editing, Methodology, Data curation. **Mark Klose:** Writing – review & editing, Methodology, Data curation. **Jeffrey S.A. Stringer:** Writing – review & editing, Supervision, Formal analysis, Data curation, Conceptualization. **Kim A. Boggess:** Writing – review & editing, Project administration, Methodology, Formal analysis, Conceptualization.

ACKNOWLEDGMENTS

Preliminary data were presented as a poster at the 2026 Society for Maternal-Fetal Medicine Pregnancy Meeting.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.ajogmf.2026.102088.

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Received Mar. 20, 2026; revised July 7, 2026; accepted Aug. 10, 2026.

Tweetable statement: Discordance between abdominal circumference and estimated fetal weight in late

pregnancy identifies risk: even isolated large abdominal circumference is linked to large-for-gestational age birth and delivery complications.

Conflicts of interest: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Funding: Personnel support has been provided through the US National Institutes of Health (T32 HD075731, K23 HD118285, and L30 HD119794) to Dr Rittenhouse. The conclusions and opinions expressed in this article are those of the authors and do not necessarily reflect those of the funders. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

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