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Improving the accuracy of screening for large-for-gestational-age fetuses: a multicenter observational study

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Abstract

Objectives: Large-for-gestational-age (LGA) fetuses present significant maternal and neonatal risks. However, prenatal screening is prone to inaccuracies, leading to potentially unnecessary interventions. This study aims to evaluate the factors influencing the accuracy of third-trimester screening for LGA fetuses to improving diagnostic accuracy.

Methods: A prospective, multicenter cohort study was conducted involving low-risk pregnancies from three hospitals. Screening was analyzed using ultrasound-based fetal weight estimation (EFW), abdominal circumference (AC) and symphysial fundal height (SFH) measurements. EFW and AC were assessed either during the routine third-trimester ultrasound or during an additional growth ultrasound when available. Newborns were classified as LGA based on AUDIPOG growth curves. Screening performance was assessed using sensitivity, specificity, predictive values, diagnostic odds ratios (DOR), Youden's index and accuracy. We also evaluated composite screening tests combining biometric parameters with maternal clinical risk factors and influence of gestational age at the time of growth ultrasound to identify the optimal timing for screening.

Results: Among 2,217 women, risk factors such as high BMI and gestational diabetes increased suspicion of LGA fetuses, contributing to both true and false positive results ($p<0.001$). No single ultrasound parameter demonstrated superior diagnostic performance. Third-trimester ultrasound showed a sensitivity of 37 % [31–44 %] and a specificity of 94 % [93–95 %], while growth ultrasound improved sensitivity to 65 % [57–74 %] but reduced specificity to 82 % [79–85 %]. SFH measurements did not enhance screening performance. Overestimation of fetal weight was observed in 56.89 % (95/167) of cases, with errors exceeding 10 % in 26.95 % (122/167) of newborns. Combined screening using fetal biometry and maternal clinical risk factors showed high specificity but poor sensitivity, limiting their utility as standalone tools for detecting macrosomia.

Conclusions: This study underscores the impact of operator bias in LGA screening, with risk factors influencing measurements. The modest performance of ultrasound-based screening highlights the inherent limitations of current methods. These findings call for cautious labeling of LGA fetuses and development of management strategies to address the challenges of imprecise screening.

Keywords: fetal macrosomia diagnosis; ultrasonography; prenatal methods; obstetric methods; decision making

Introduction

Large-for-gestational-age (LGA) fetuses are defined by an estimated fetal weight (EFW) exceeding the 90th percentile or weighing more than 4,000 g. Delivering an LGA fetus is associated with an increased risk of complications, which can be severe [1]. These complications may be fetal (e.g., shoulder dystocia) or maternal (e.g., perineal injury, postpartum hemorrhage). Both fetal and neonatal morbidity and mortality rise significantly from 4,000 g [2] with an even steeper increase after 4,500 g [3]. To mitigate these risks, several delivery strategies, including early induction of labor [4], have been proposed. However, these interventions rely on the prenatal suspicion of LGA, which can only be confirmed postpartum.

The imprecision of ultrasound-based screening for LGA fetuses is well-documented, with frequent overestimations [5–8]. Many studies, using criteria often stricter than those in clinical practice, highlight a significant risk of false positives, which can lead to inappropriate interventions, such as

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unnecessary labor inductions. Measurement of symphysial fundal height (SFH, also known as uterine height or fundal height) has been suggested as a complementary tool to enhance screening accuracy, but findings in the literature are inconsistent [9–11]. Moreover, suspicion of an LGA fetus has been linked to unintended "side effects" [12–14], including higher cesarean rates, even for neonates with normal birth weights. These findings underscore the critical need for reliable screening methods to minimize the potential for mismanagement.

The objectives of this study are twofold: to identify factors associated with the success or failure of third-trimester screening for LGA fetuses and to determine which clinical or ultrasound parameters should be prioritized to enhance screening accuracy.

Materials and methods

This prospective, observational, multicenter cohort study was conducted in three French hospitals: Centre Hospitalier Universitaire de Reims, Centre Hospitalier de Châlons-en-Champagne, and Centre Hospitalier de Charleville-Mézières. The study included women with low-risk singleton pregnancies, defined as pregnancies with a singleton fetus in cephalic presentation and without significant maternal or fetal pathologies, apart from gestational diabetes. Recruitment occurred during routine third-trimester ultrasounds between October 1, 2020, and September 30, 2021, contingent on patient non-opposition. Participation did not alter clinical follow-up or management, as all procedures adhered to pre-established, standardized protocols that were identical across the three centers.

The inclusion and exclusion criteria for this study were derived from a previously published research protocol investigating the management of suspected LGA fetuses [12]. These criteria were established to align with the objectives of the initial study. Patients were eligible for inclusion if they had undergone a dating ultrasound before 14 weeks of gestation to confirm pregnancy dates and met the criteria for a low-risk pregnancy. Exclusion criteria were carefully defined to maintain the study's focus on uncomplicated pregnancies. Women were excluded if they had a history of obstetric trauma (e.g., shoulder dystocia, severe perineal injury, or pelvic floor damage), psychological complications related to previous deliveries, or prior cesarean sections. Other exclusion criteria included pre-existing maternal conditions such as pre-eclampsia, chronic hypertension, or premature rupture of membranes, as well as known fetal anomalies, including growth restrictions or congenital malformations. Additionally, deliveries before 37 weeks of gestation, non-cephalic presentations at birth, incomplete follow-up data, or deliveries occurring outside the participating centers led to exclusion from the analysis.

All participants underwent a standardized third-trimester ultrasound between 30 and 34 weeks of gestation (WG), following a unified protocol established across the three centers. Estimated fetal weight (EFW) was calculated using Hadlock's formula which incorporates head circumference (HC), abdominal circumference (AC), and femur length (FL): $\log_{10}$ EFW=1.326 + 0.0107HC + 0.0438AC + 0.158FL + 0.00326 (ACxFL) [15]. In cases of suspected LGA fetuses, a follow-up growth ultrasound was systematically performed around 36 weeks. Monthly prenatal visits included measurements of symphysial fundal height (SFH) using a tape measure. This measurement was performed by palpating the pubic bone and uterine fundus and recording the distance between these landmarks [16]. SFH thresholds were pre-defined [17], with strict adherence to the shared protocol to ensure consistency across all three centers.

To assess the performance of prenatal screening for LGA neonates, we conducted a comparative analysis of four diagnostic groups based on birth outcomes and prenatal ultrasound findings (third trimester ultrasound and growth ultrasound around 36 weeks of gestation): true positives (TP, LGA neonates correctly identified), false positives (FP, AGA neonates incorrectly classified as LGA), false negatives (FN, LGA neonates incorrectly classified as AGA), and true negatives (TN, AGA neonates correctly identified). Diagnostic performance metrics included sensitivity, specificity, positive and negative predictive values, accuracy, diagnostic

Table 1: Women characteristics (n=2,217).

Characteristics	
Age, years, median (interquartile range)	29 (7)
BMI, kg/m^2, median (interquartile range)	24.77 (7.70)
Parity, n (%)	
Nulliparous	980 (44.20)
Primiparous	666 (30.04)
Multiparous	571 (25.76)
History of LGA fetus, n (%)	99 (4.47)
History of diabetes, n (%)	106 (4.78)
Gestational diabetes, n (%)	448 (20.21)
Including balanced diabetes	297 (70.71)
Including insulin-treated diabetes	175 (41.27)
Amount of amniotic fluid, n (%)	
Decreased	6 (0.27)
Increased	16 (0.72)
Normal	2,195 (99.01)
Fetal weight at birth, g, mean ± standard deviation	3,360.17 ± 449.50

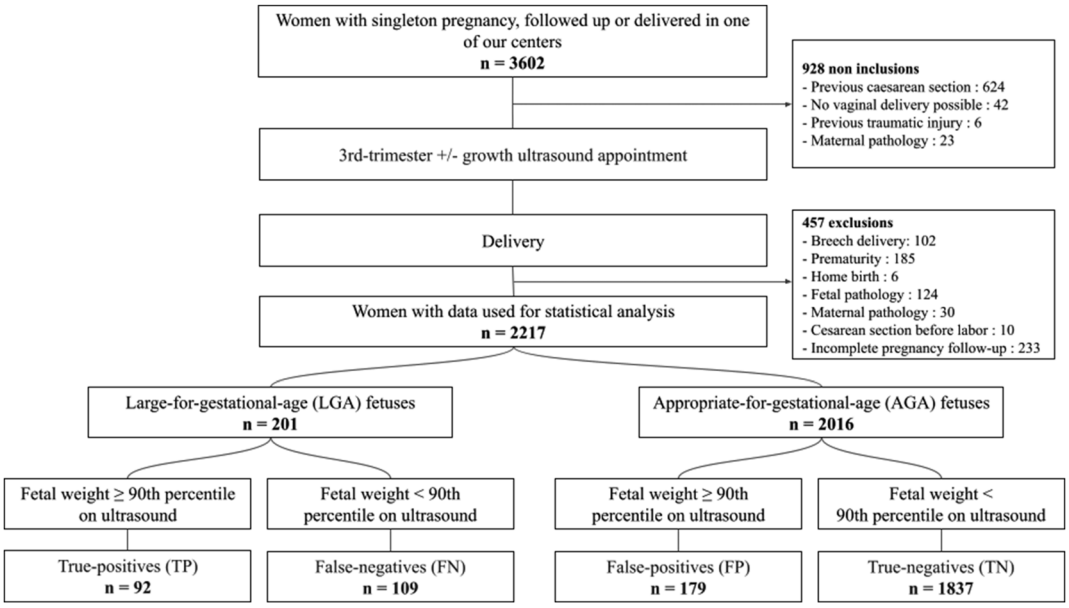

Figure 1: Patient selection flow-chart.

Table 2: Performance of ultrasound and clinical parameters for LGA fetuses screening (n=2,217).

		Sensitivity	Specificity	PPV[f]	NPV[d]	DOR[b]	Youden's index	Accuracy
SFH[g] (n=2,144)		0.85 [0.79–0.80]	0.39 [0.37–0.41]	0.12 [0.10–0.14]	0.96 [0.97–0.95]	3.50 [2.35–5.22]	0.24	0.43
3rd-trimester ultrasound (n=2,217)	AC[a]≥90th per[e]	0.36 [0.29–0.42]	0.93 [0.92–0.94]	0.35 [0.28–0.41]	0.94 [0.93–0.95]	7.72 [5.51–10.81]	0.29	0.88
	AC[a]≥97th per[e]	0.18 [0.05–0.3]	0.98 [0.98–0.99]	0.15 [0.07–0.3]	0.99 [0.98–0.99]	13.54 [5.27–34.83]	0.16	0.97
	EFW[c]≥90th per[e]	0.37 [0.31–0.44]	0.94 [0.93–0.95]	0.39 [0.37–0.41]	0.94 [0.93–0.95]	9.49 [6.75–13.34]	0.31	0.89
	EFW[c]≥97th per[e]	0.18 [0.05–0.3]	0.97 [0.97–0.98]	0.10 [0.04–0.2]	0.99 [0.98–0.99]	8.14 [3.24–20.44]	0.15	0.96
Growth ultrasound (AC[a]: n=781) (EFW[c]: n=896)	AC[a]≥400 mm	0 [0–0]	1 [1–1]		0.85 [0.83–0.88]	0 [0–0]		0.85
	AC[a]≥90th per[e]	0.68 [0.59–0.76]	0.81 [0.78–0.84]	0.38 [0.32–0.45]	0.94 [0.91–0.95]	9.12 [5.89–14.12]	0.49	0.79
	AC[a]≥97th per[e]	0.54 [0.34–0.74]	0.92 [0.9–0.94]	0.18 [0.11–0.28]	0.98 [0.97–0.99]	13.73 [5.9–31.97]	0.46	0.91
	EFW[c]≥4,000 g	0.11 [0.06–0.16]	0.99 [0.98–1]	0.67 [0.45–0.83]	0.87 [0.85–0.89]	13.49 [5.33–34.13]	0.10	0.87
	EFW[c]≥90th per[e]	0.65 [0.57–0.74]	0.82 [0.79–0.85]	0.38 [0.31–0.44]	0.93 [0.92–0.95]	8.63 [5.73–12.99]	0.47	0.80
	EFW[c]≥97th per[e]	0.46 [0.27–0.65]	0.91 [0.89–0.93]	0.13 [0.08–0.22]	0.98 [0.97–0.99]	8.46 [3.79–18.92]	0.37	0.90
Growth ultrasound + SFH[g] (AC[a]: n=741) (EFW[c]: n=855)	AC[a]≥400 mm	0 [0–0]	1 [1–1]		0.85 [0.83–0.88]	0 [0–0]		0.85
	AC[a]≥90th per[e]	0.62 [0.53–0.71]	0.82 [0.79–0.85]	0.38 [0.31–0.45]	0.93 [0.91–0.95]	7.7 [4.97–11.93]	0.45	0.87
	AC[a]≥97th per[e]	0.55 [0.34–0.75]	0.93 [0.91–0.95]	0.18 [0.11–0.3]	0.99 [0.97–0.99]	15.08 [6.23–36.52]	0.47	0.91
	EFW[c]≥4,000 g	0.08 [0.03–0.13]	0.99 [0.99–1]	0.71 [0.44–0.89]	0.87 [0.85–0.89]	16.44 [5.07–53.33]	0.08	0.87]
	EFW[c]≥90th per[e]	0.60 [0.51–0.68]	0.83 [0.81–0.86]	0.37 [0.31–0.44]	0.93 [0.91–0.94]	7.37 [4.88–11.13]	0.43	0.80
	EFW[c]≥97th per[e]	0.46 [0.26–0.66]	0.92 [0.9–0.93]	0.14 [0.08–0.23]	0.98 [0.97–0.99]	9.20 [3.97–21.3]	0.37	0.90
3rd-trimester and growth ultrasound concordance (AC[a]: n=741) (EFW[c]: n=855)	AC[a]≥90th per[e]	0.56 [0.46–0.67]	0.90 [0.88–0.93]	0.42 [0.33–0.51]	0.94 [0.92–0.96]	12.18 [7.41–20.03]	0.47	0.87
	AC[a]≥97th per[e]	0.12 [0.00–0.26]	0.99 [0.98–1]	0.30 [0.01–0.62]	0.93 [0.96–0.98]	15.31 [3.70–63.34]	0.12	0.96
	EFW[c]≥90th per[e]	0.53 [0.44–0.63]	0.91 [0.89–0.93]	0.43 [0.34–0.51]	0.94 [0.92–0.95]	11.38 [7.19–18.01]	0.44	0.87
	EFW[c]≥97th per[e]	0.15 [0.02–0.29]	0.98 [0.97–0.99]	0.16 [0.06–0.36]	0.97 [0.96–0.98]	7.35 [2.33–23.21]	0.13	0.95

[a]AC, abdominal circumference; [b]DOR, diagnostic odds ratio; [c]EFW, estimated fetal weight; [d]NPV, negative predictive value; [e]per, percentile; [f]PPV, positive predictive value; [g]SFH, symphysial fundal height.

odds ratio, and Youden's index. This classification allowed us to evaluate the clinical and demographic factors associated with correct (TP and TN) or incorrect (FP and FN) identification of fetal size. This analysis aimed to explore under what circumstances the screening process was more or less effective.

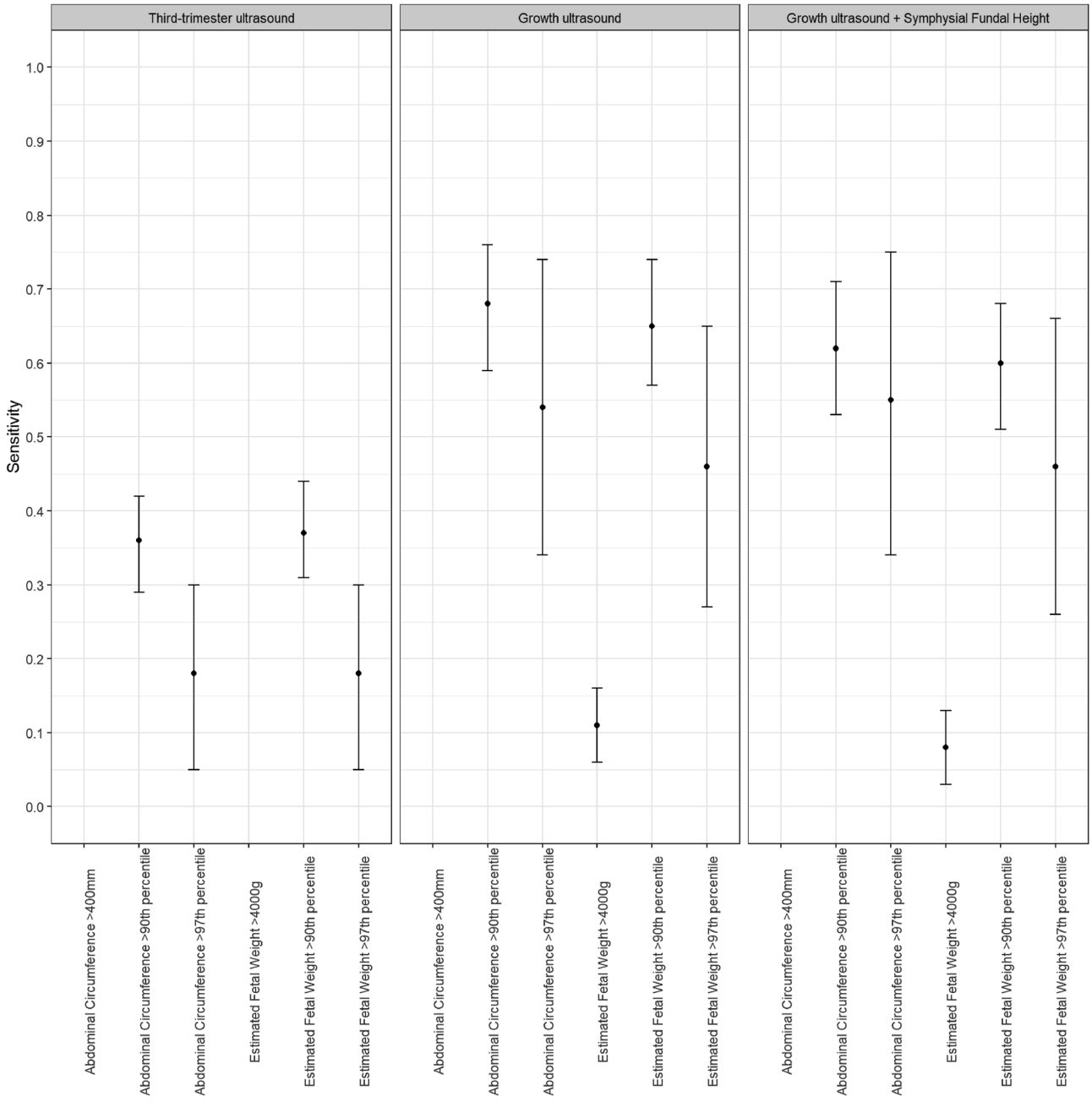

Figure 2: Sensitivity of ultrasound by ultrasound parameters.

Then, clinical parameters with a statistically significant association ($p<0.05$) were selected for further analysis: each of these clinical factors was combined with one of ultrasound growth criteria (abdominal circumference or estimated fetal weight >90th percentile) obtained during the third-trimester or scan: A combined test was considered positive only when both the ultrasound growth criterion and the selected clinical parameter were positive. We then evaluated the diagnostic performance (sensitivity, specificity, positive predictive value, negative predictive value, accuracy, Youden's index, and diagnostic odds ratio) of each composite criterion.

Newborns were classified as large for gestational age (LGA) if their birth weight exceeded the 90th percentile according to the AUDIPOG-adjusted growth curves [18, 19]. They were then considered correctly screened if their estimated fetal weight (EFW) during the growth ultrasound – or, if unavailable, during the third-trimester ultrasound – was at or above the 90th percentile based on the 2014 Collège Français d'Échographie Fœtale (CFEF) growth

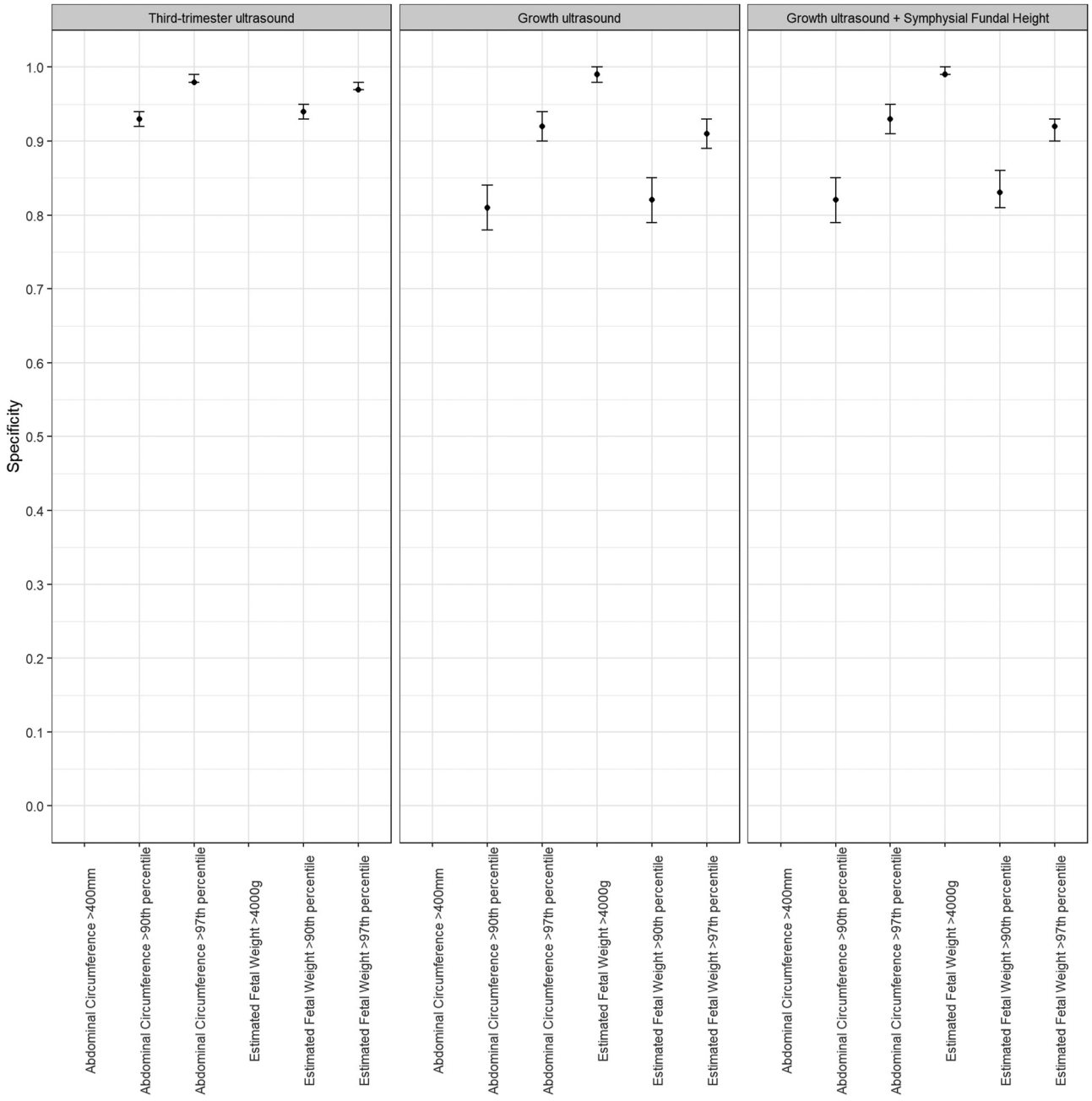

Figure 3: Specificity of ultrasound by ultrasound parameters.

charts [20]. Parity was determined based on the number of deliveries before the current pregnancy. A patient was considered to have a personal history of LGA if she had previously delivered a newborn weighing more than 4,000 g or exceeding the 90th percentile on the AUDIPOG-adjusted growth curves [18, 19]. Gestational diabetes was classified as well controlled if at least 70 % of blood glucose measurements – monitored six times daily in accordance with a standardized protocol across all participating centers – remained within target ranges (≤0.95 g/L fasting and ≤1.20 g/L 2 h postprandial).

Data were recorded by study staff until discharge. Ultrasound equipment was of similar quality in all hospitals. The average follow-up was four days (until discharge).

Statistical analyses were conducted using R, version 4.3.1 (The R Foundation for Statistical Computing, Vienna, Austria), with results described as means (± standard deviation) for continuous variables and counts with percentages

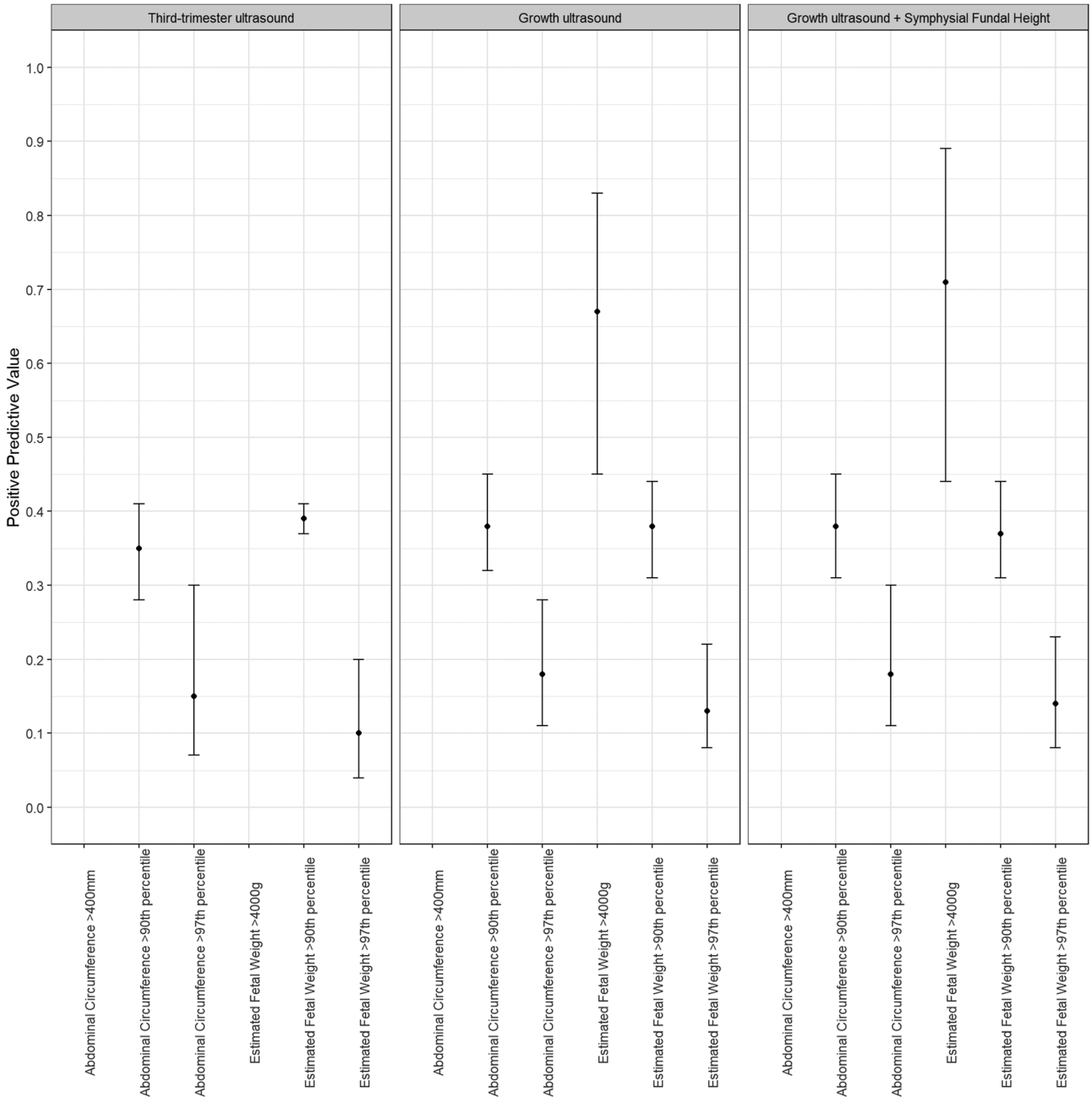

Figure 4: Positive predictive value of ultrasound by ultrasound parameters.

for categorical variables. Statistical comparisons between groups were performed using the Wilcoxon rank-sum test for continuous variables. Categorical variables were compared using the Chi-squared test. Missing data led to exclusion from specific analyses. A p-value <0.05 was considered statistically significant.

This study was conducted in accordance with the World Medical Association's Declaration of Helsinki, ensuring ethical standards for research involving human participants.

Results

The study enrolled 2,217 women, with detailed characteristics summarized in Table 1. Figure 1 illustrates the patient selection process.

Performance metrics for individual ultrasound parameters are detailed in Table 2 and Figures 2–6, including symphysis-fundal height measurements and isolated ultrasound criteria. Standard screening strategies demonstrated variable diagnostic performance. SFH measurements

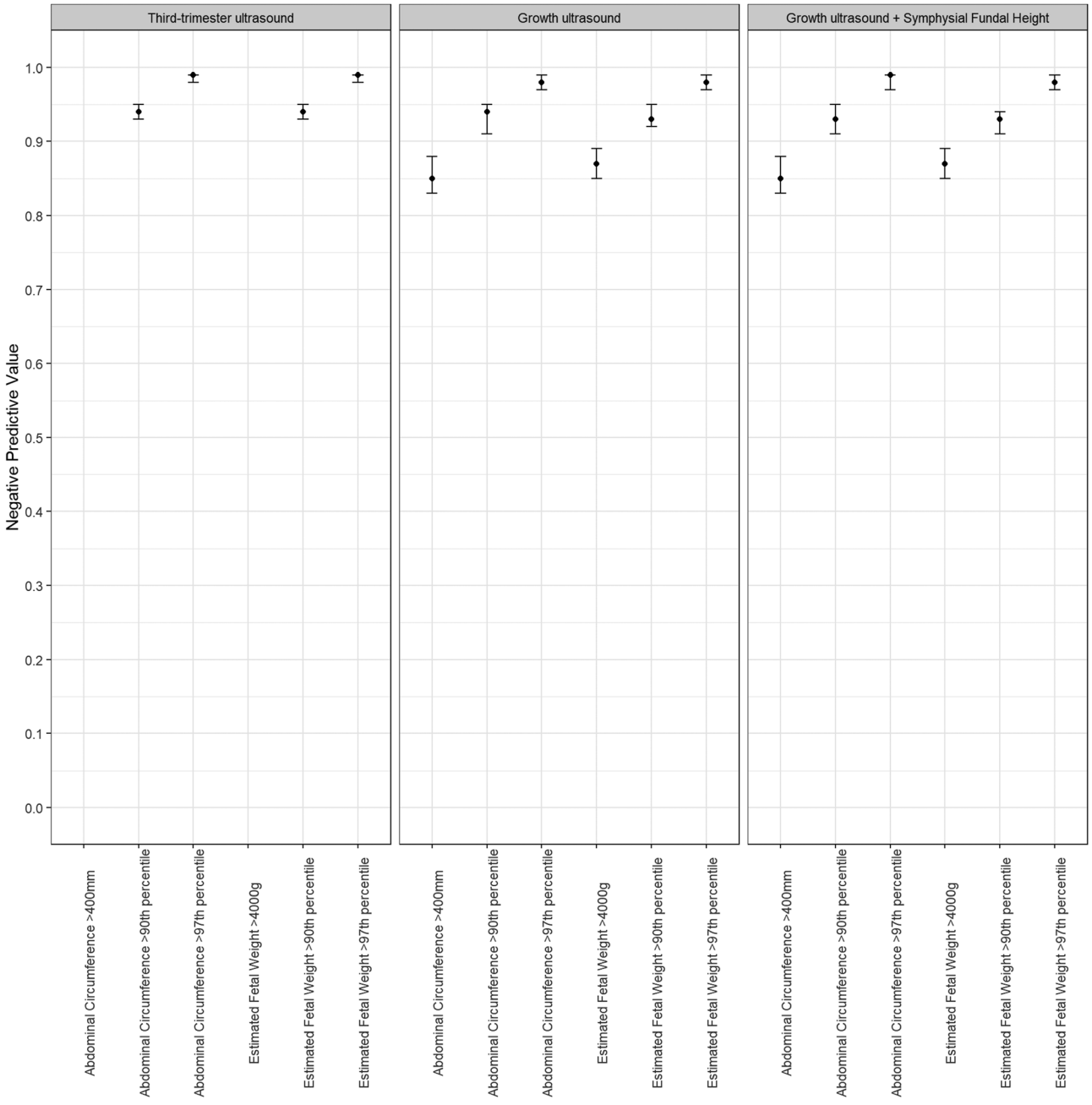

Figure 5: Negative predictive value of ultrasound by ultrasound parameters.

showed high sensitivity but poor specificity, while third-trimester ultrasound thresholds offered more balanced trade-offs between sensitivity and specificity. More extreme biometric cutoffs (e.g., ≥97th percentile or EFW≥4,000 g) improved specificity and positive predictive value but at the cost of markedly reduced sensitivity. These results highlight the inherent limitations of current routine screening tools when used in isolation.

Tables 3 and Figures 7–11 illustrate the diagnostic performance of various ultrasound parameters during growth ultrasounds, analyzed by the gestational age at which they were performed. No significant differences in performance were observed across the different gestational ages.

The diagnosis was accurate (true positive or true negative) in 79.69 % of cases when using the parameter most commonly employed by the participating teams: EFW >90th percentile for gestational age on growth ultrasound. Among the positive test results, 62.44 % (138/221) were false positives. The relative error in fetal weight estimation exceeded 10 % in 26.95 % of newborns and surpassed 20 % in 6.59 % of cases.

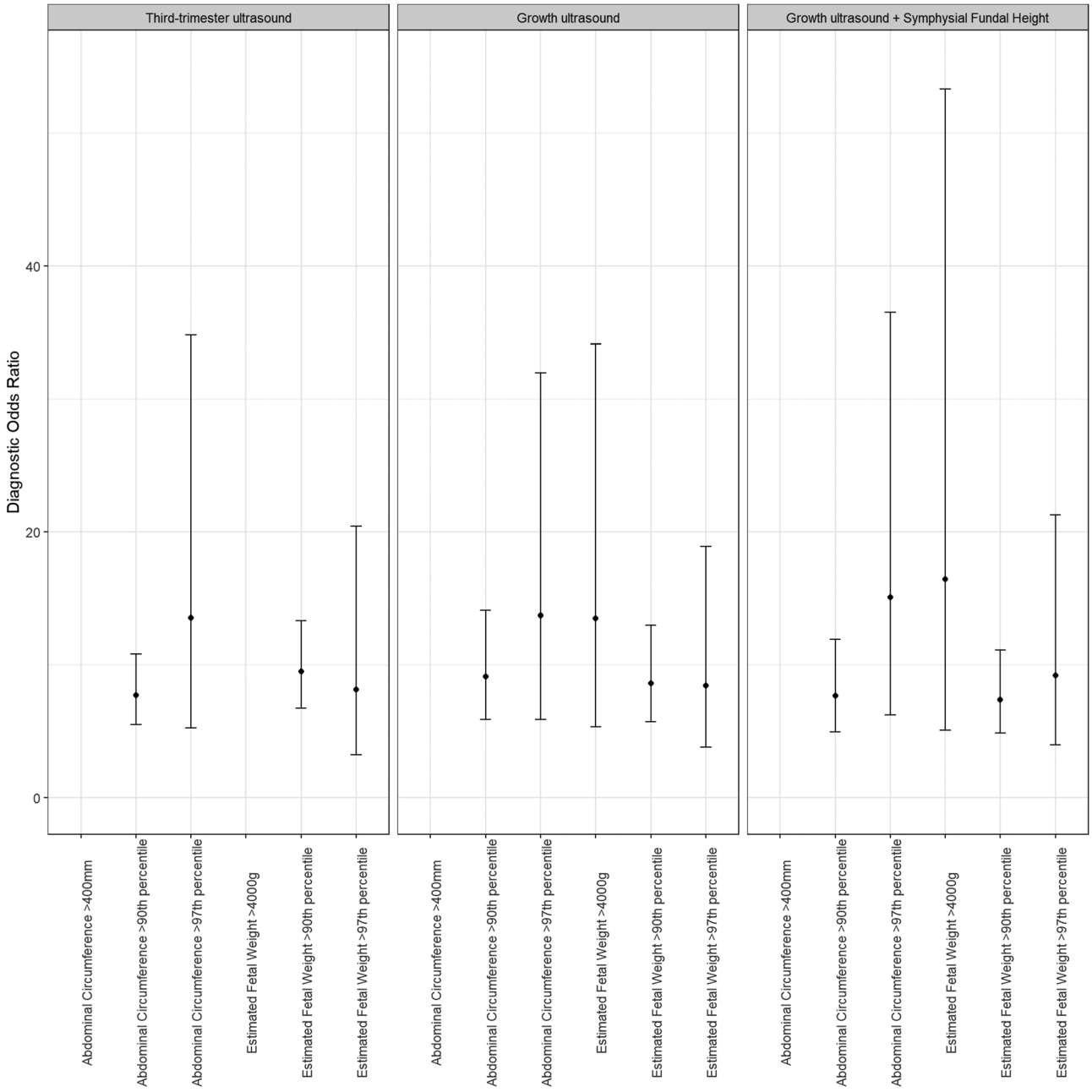

Figure 6: Diagnostic odds ratio of ultrasound by ultrasound parameters.

Weight overestimation was more common than underestimation, occurring in 56.89 % (95/167) of cases compared to 40.72 % (68/167). Weight estimation discrepancies, illustrated in Figure 12, revealed overestimations in 57 % of cases, with relative errors exceeding 10 % in 26.95 % (45/167) of newborns.

Performance metrics for clinical parameters are detailed in Table 4. High BMI and gestational diabetes were significantly associated with increased suspicion of LGA fetuses, both correctly (true positives, $p<0.001$) and incorrectly (false positives, $p<0.001$). Histories of LGA births or diabetes similarly correlated with false positives ($p<0.01$). All parameters demonstrated diagnostic utility (DOR>1), except for abdominal circumference during growth ultrasound, which showed limited sensitivity but higher specificity and positive predictive value. EFW thresholds of 4,000 g exhibited the highest specificity but the lowest sensitivity. Adding SFH measurements did not significantly enhance diagnostic performance. Notably, requiring LGA confirmation by both third-trimester and growth ultrasounds increased specificity and accuracy compared to either ultrasound alone.

Table 3: Performance of ultrasound parameters for LGA fetuses screening during the growth ultrasound according to gestational age.

		Sensitivity	Specificity	PPV[f]	NPV[d]	DOR[b]	Youden's index	Accuracy
35 WG[h] (n=83)	AC[a]≥90th per[e]	0.6 [0.17–1.00]	0.44 [0.21–0.67]	0.23 [0.08–0.52]	0.8 [0.46–0.95]	0.04 [−0.44–0.53]	1.2	0.48
	AC[a]≥97th per[e]		0.91 [0.79–1.03]	0.00 [0.00–0.00]	1.00 [1.00–1.00]			0.91
	EFW[c]≥90th per[e]	0.2 [0.00–0.55]	0.52 [0.32–0.73]	0.08 [0.01–0.41]	0.75 [0.49–0.9]	−0.28 [−0.68–0.13]	0.27	0.46
	EFW[c]≥97th per[e]	1.00 [1.00–1.00]	0.83 [0.69–0.97]	0.17 [0.02–0.63]	1.00 [1.00–1.00]	0.83 [0.69–0.97]		0.83
36 WG[h] (n=197)	AC[a]≥90th per[e]	0.59 [0.35–0.82]	0.63 [0.5–0.77]	0.34 [0.2–0.53]	0.82 [0.68–0.91]	0.22 [−0.05–0.49]	2.48	0.62
	AC[a]≥97th per[e]	0.5 [0.00–1.00]	0.83 [0.73–0.93]	0.1 [0.01–0.47]	0.98 [0.86–1.00]	0.33 [−0.37–1.03]	4.89	0.82
	EFW[c]≥90th per[e]	0.63 [0.41–0.85]	0.73 [0.61–0.84]	0.41 [0.25–0.6]	0.87 [0.74–0.93]	0.36 [0.11–0.6]	4.54	0.7
	EFW[c]≥97th per[e]	0.00 [0.00–0.00]	0.86 [0.78–0.95]	0.00 [0.00–0.00]	0.97 [0.87–0.99]	−0.14 [−0.22–0.05]	0	0.84
37 WG[h] (n=232)	AC[a]≥90th per[e]	0.65 [0.44–0.86]	0.69 [0.57–0.8]	0.41 [0.25–0.58]	0.86 [0.73–0.93]	0.34 [0.1–0.58]	4.11	0.68
	AC[a]≥97th per[e]	0.25 [0.00–0.67]	0.91 [0.86–0.97]	0.11 [0.02–0.5]	0.97 [0.9–0.99]	0.16 [−0.26–0.59]	3.54	0.89
	EFW[c]≥90th per[e]	0.73 [0.54–0.91]	0.69 [0.59–0.79]	0.39 [0.25–0.55]	0.9 [0.8–0.96]	0.41 [0.2–0.63]	5.87	0.7
	EFW[c]≥97th per[e]	0.2 [0.00–0.55]	0.86 [0.79–0.92]	0.06 [0.01–0.32]	0.96 [0.9–0.98]	0.06 [−0.3–0.41]	1.48	0.83
38 WG[h] (n=230)	AC[a]≥90th per[e]	0.85 [0.73–0.97]	0.48 [0.35–0.61]	0.49 [0.37–0.62]	0.85 [0.68–0.94]	0.34 [0.16–0.51]	5.41	0.62
	AC[a]≥97th per[e]	0.5 [0.15–0.85]	0.78 [0.7–0.86]	0.16 [0.06–0.36]	0.95 [0.87–0.98]	0.28 [−0.07–0.64]	3.57	0.76
	EFW[c]≥90th per[e]	0.76 [0.63–0.9]	0.5 [0.38–0.62]	0.45 [0.33–0.57]	0.8 [0.66–0.89]	0.26 [0.09–0.44]	3.22	0.59
	EFW[c]≥97th per[e]	0.62 [0.29–0.96]	0.76 [0.68–0.84]	0.16 [0.07–0.33]	0.96 [0.9–0.99]	0.38 [0.04–0.73]	5.26	0.75
39 WG[h] (n=53)	AC[a]≥90th per[e]	0.6 [0.3–0.9]	0.59 [0.35–0.82]	0.46 [0.22–0.72]	0.71 [0.44–0.89]	0.19 [−0.2–0.57]	2.14	0.59
	AC[a]≥97th per[e]	0.5 [0.00–1.00]	0.6 [0.39–0.81]	0.11 [0.02–0.5]	0.92 [0.61–0.99]	0.1 [−0.63–0.83]	1.5	0.59
	EFW[c]≥90th per[e]	0.82 [0.59–1.00]	0.42 [0.2–0.64]	0.45 [0.25–0.66]	0.8 [0.46–0.95]	0.24 [−0.08–0.56]	3.27	0.57
	EFW[c]≥97th per[e]	0.5 [0.00–1.00]	0.71 [0.53–0.89]	0.12 [0.02–0.54]	0.94 [0.69–0.99]	0.21 [−0.51–0.92]	2.43	0.69

[a]AC, abdominal circumference; [b]DOR, diagnostic odds ratio; [c]EFW, estimated fetal weight; [d]NPV, negative predictive value; [e]per, percentile; [f]PPV, positive predictive value; [g]SFH, symphysial fundal height; [h]WG, weeks of gestation.

To further assess the potential added value of maternal clinical characteristics, we evaluated a series of composite tests combining fetal biometric thresholds (AC or EFW≥90th percentile at third trimester ultrasound) with identified maternal risk factors. The diagnostic performance of these combinations is detailed in Table 5. These combinations yielded high specificity (96–100 %) but low sensitivity (4–23 %). The best-performing combinations involved a history of diabetes or fetal macrosomia, with positive predictive values up to 0.73 and diagnostic odds ratios up to 29.1. However, all combinations demonstrated limited overall diagnostic performance, with modest Youden's indices (≤0.20) and stable accuracy around 0.90. Compared to abdominal circumference, tests using EFW showed slightly improved performance, particularly in VPP and odds ratios, though differences were modest.

Discussion

This study highlights how the identification of risk factors for LGA fetuses often leads to their classification as LGA, regardless of accuracy. Our findings indicate that no single ultrasound parameter consistently outperformed others in either screening or confirming LGA status. This suggests that the tools currently available lack the precision needed to reliably differentiate between true and false diagnoses.

The diagnostic performance results are consistent with those reported in the literature. A meta-analysis [21] including 41 studies and a total of 112,034 patients reported a sensitivity of 53.2 % for estimated fetal weight above 4,000 g (or the 90th percentile) and a specificity of 93.9 %. For higher thresholds (4,500 g or the 97th percentile), sensitivity and specificity were 67.5% and 89.7 %, respectively. When considering abdominal circumference above the 90th percentile, sensitivity was 57.8 % and specificity 92.3 %. The authors particularly noted significant heterogeneity in third-trimester ultrasound prediction of macrosomia. In another study [8], positive and negative predictive values were estimated at 0.67 and 0.87 for the 4,000 g threshold, and 0.44 and 0.97 for the 4,500 g threshold, respectively. Milner et al. [5] reported a fetal weight estimation error rate ranging from 7 to 22 %, depending on the formula used, with a strong tendency toward overestimation. Another team [22] reported a mean absolute error between 8.4% and 9.0 %. The proportion of newborns for whom the estimation error was less than 10 % ranged from 63 to 74 % across different studies [22, 23].

Our results support the view that growth ultrasounds are the most reliable tool for detecting LGA fetuses, corroborating findings from prior studies [24]. However, we

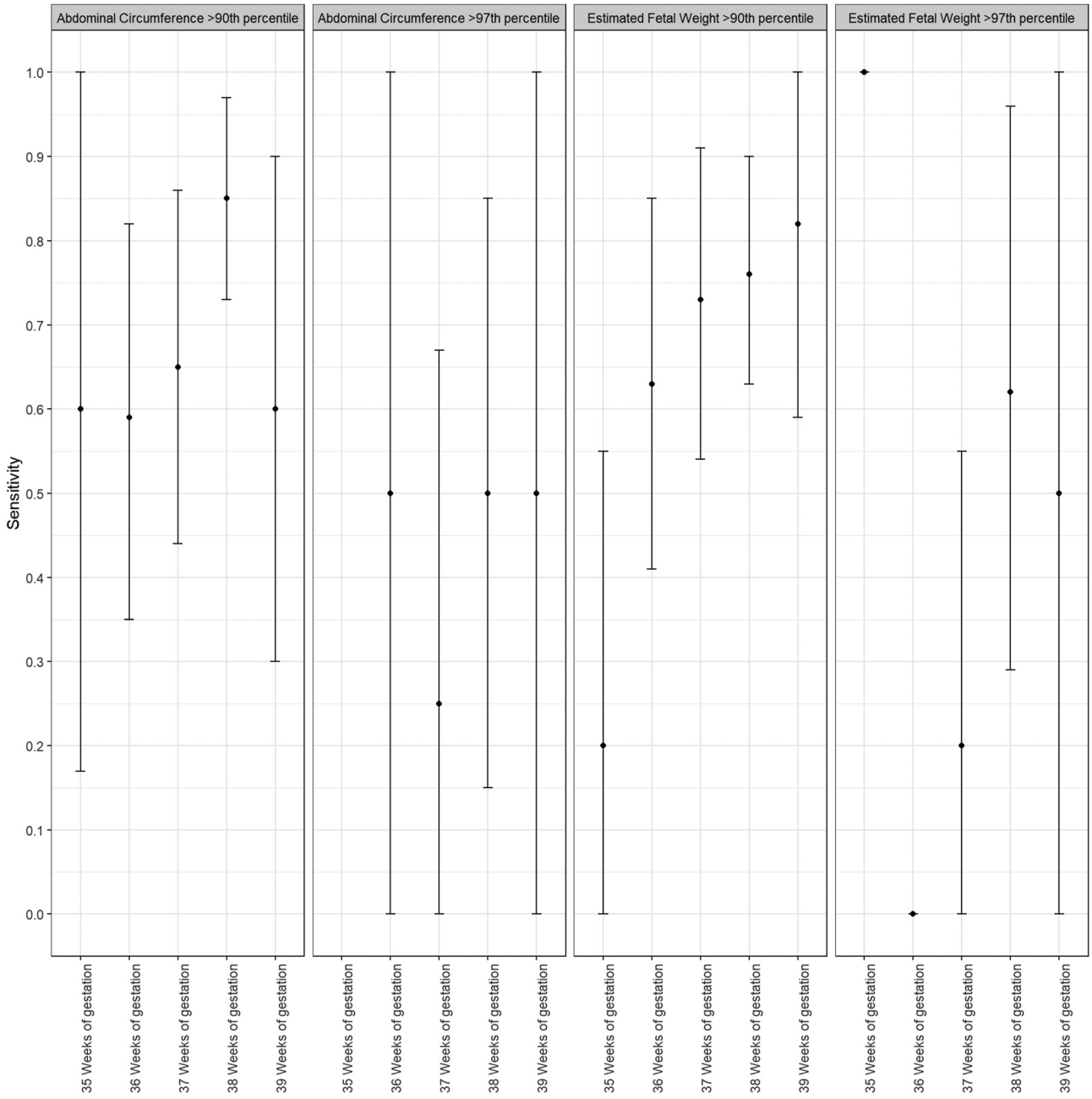

Figure 7: Sensitivity of ultrasound parameters by time of screening.

were unable to identify a specific gestational age at which this examination was most effective. This limitation could stem from the small sample sizes in certain subgroups or a genuine lack of variation in accuracy within the analyzed timeframes.

Regarding SFH measurements, our study showed no significant improvement in screening accuracy when these were combined with ultrasound parameters. This contrasts with some literature reporting moderate sensitivity and specificity for SFH thresholds, particularly when combined with weight thresholds such as 4,000 g [10, 11, 25, 26]. However, methodological differences could explain this discrepancy. Notably, our study found an exceptionally high frequency (63 %) of SFH measurements exceeding the established thresholds, which is much higher than in other cohorts, where rates are as low as 13.8 %. This difference may reflect inter-operator variability [27] and the perception of SFH as a preliminary screening tool rather than a definitive diagnostic criterion. Additionally, we chose not to train participating teams in SFH measurement to maintain a

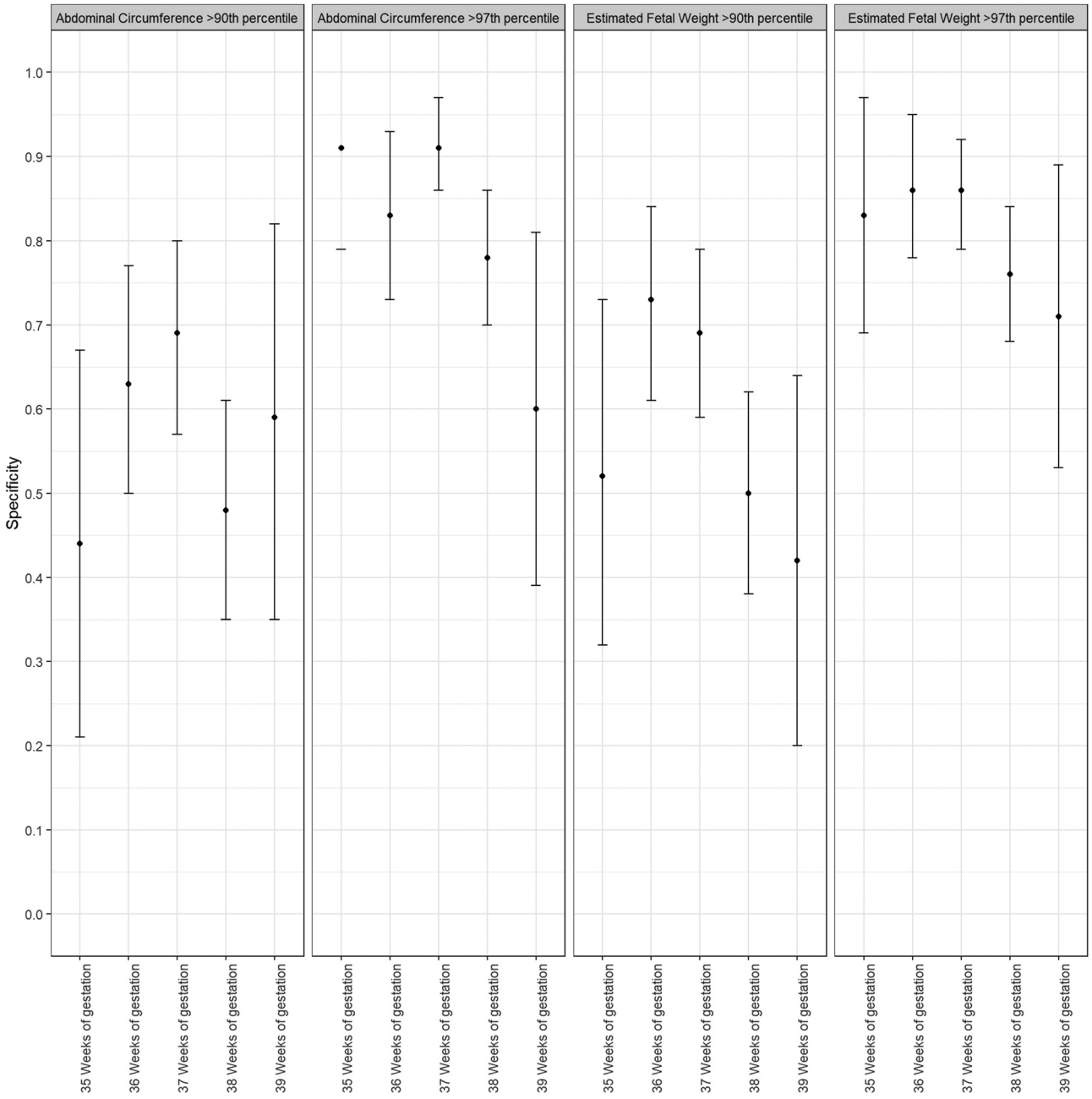

Figure 8: Specificity of ultrasound parameters by time of screening.

"real-world" approach. While this decision preserved ecological validity, it may have introduced variability that slightly diminished accuracy.

Higher BMI was notably associated with improved screening success for LGA fetuses. However, it is well-documented that elevated BMI reduces the accuracy of both ultrasound-derived [28, 29] and clinical [30] estimates of fetal weight. Interestingly, the false positive group in our study exhibited a higher prevalence of known LGA risk factors, including elevated BMI, multiparity, prior LGA deliveries, and gestational diabetes [31–34]. These findings align with previous research but also raise concerns about the role of cognitive biases in ultrasound evaluation [35]. Specifically, observer-expectancy bias – a form of cognitive bias where operators subconsciously align measurements with their expectations – may explain why these risk factors influenced outcomes. This bias is rarely quantified in ultrasound evaluation. For instance, caliper positioning during ultrasound measurements may be swayed by the operator's anticipation of an LGA fetus, particularly given that many

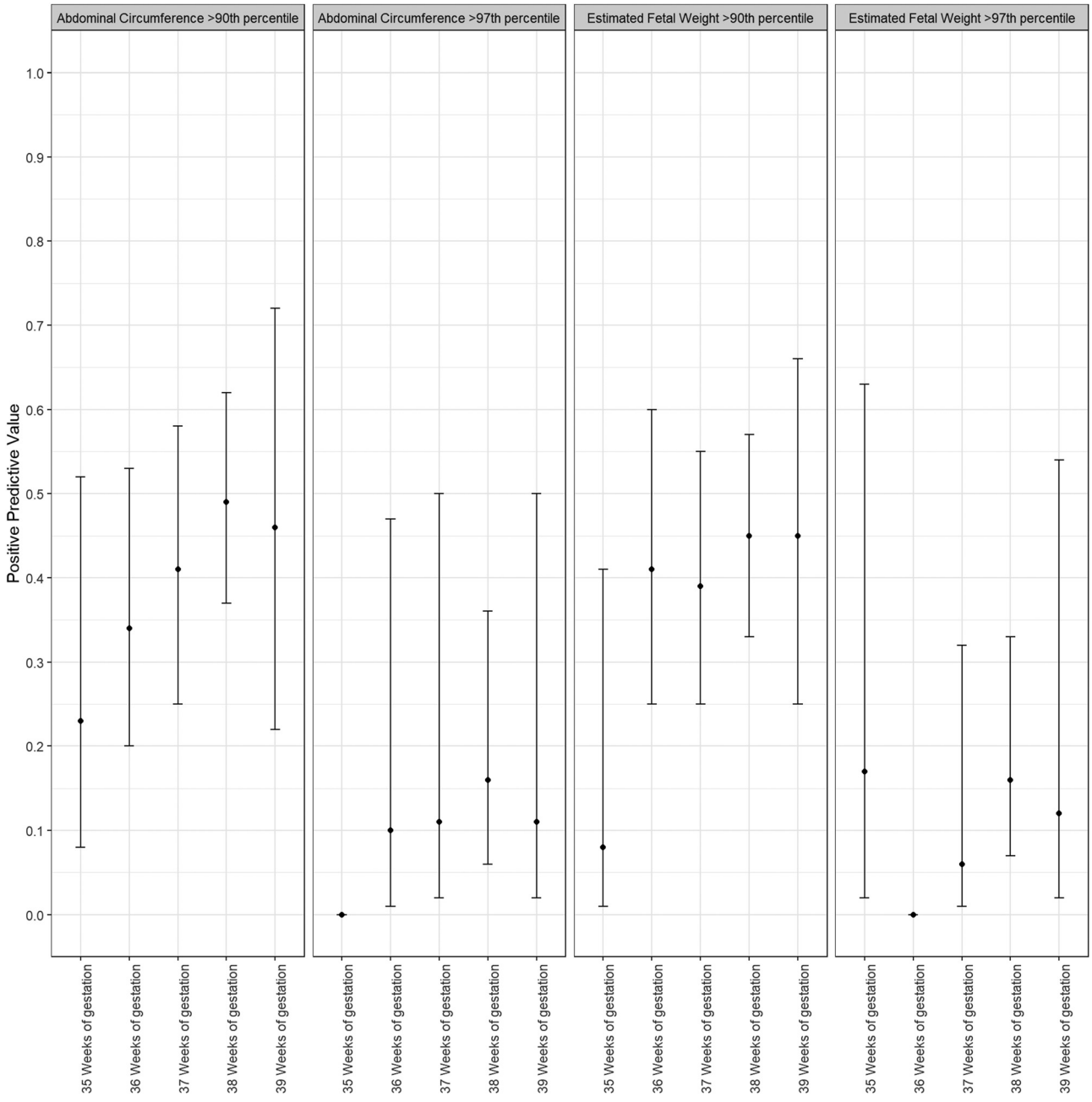

Figure 9: Positive predictive value of ultrasound parameters by time of screening.

ultrasound systems display real-time percentile rankings [36]. This phenomenon underscores the potential for operator preconceptions to affect LGA screening outcomes, leading to both overdiagnosis and unnecessary interventions. The same risk factor may serve as both a predictor of successful screening in one group and a marker of failure in another. This dual role strongly suggests the presence of confirmation bias or observer-expectancy bias, where operators, influenced by pre-existing risk factors, unconsciously adjust their measurements to align with an anticipated LGA diagnosis. In our view, this highlights how LGA fetal screening is not purely objective but can be shaped by operator preconceptions, ultimately affecting diagnostic accuracy.

Diagnostic performance of screening tests for fetal macrosomia was generally limited by low sensitivity, despite excellent specificity across all combinations. Tests combining biometric criteria (AC or EFW≥90th percentile) with maternal risk factors such as BMI≥25 or a history of

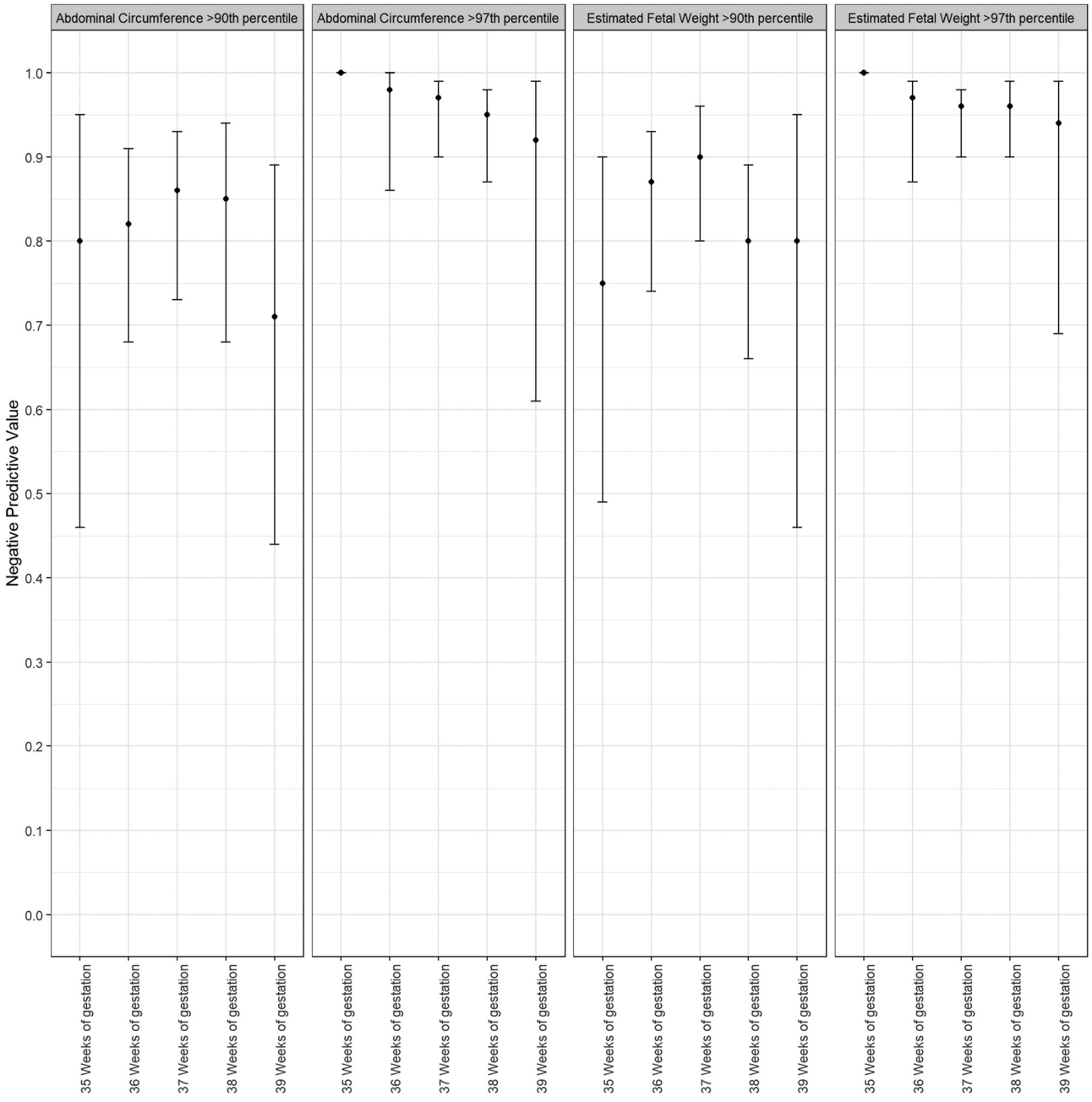

Figure 10: Negative predictive value of ultrasound parameters by time of screening.

diabetes yielded high specificity (96–100 %) and favorable diagnostic odds ratios (e.g., 29.1 for history of diabetes), indicating that positive results are highly predictive.

While adding maternal risk factors to fetal biometric thresholds slightly improves specificity and predictive values, the overall diagnostic performance remains limited by persistently low sensitivity. These results suggest that clinical risk factors alone may not substantially enhance current screening strategies, but could contribute meaningfully within targeted or multivariable prediction approaches.

One of the key strengths of our study is the use of AUDIPOG-adjusted growth curves to classify neonates. This approach, widely used in French perinatal care, accounts for maternal (e.g., parity, BMI) and neonatal (e.g., sex) factors, providing a nuanced risk assessment for obstetric

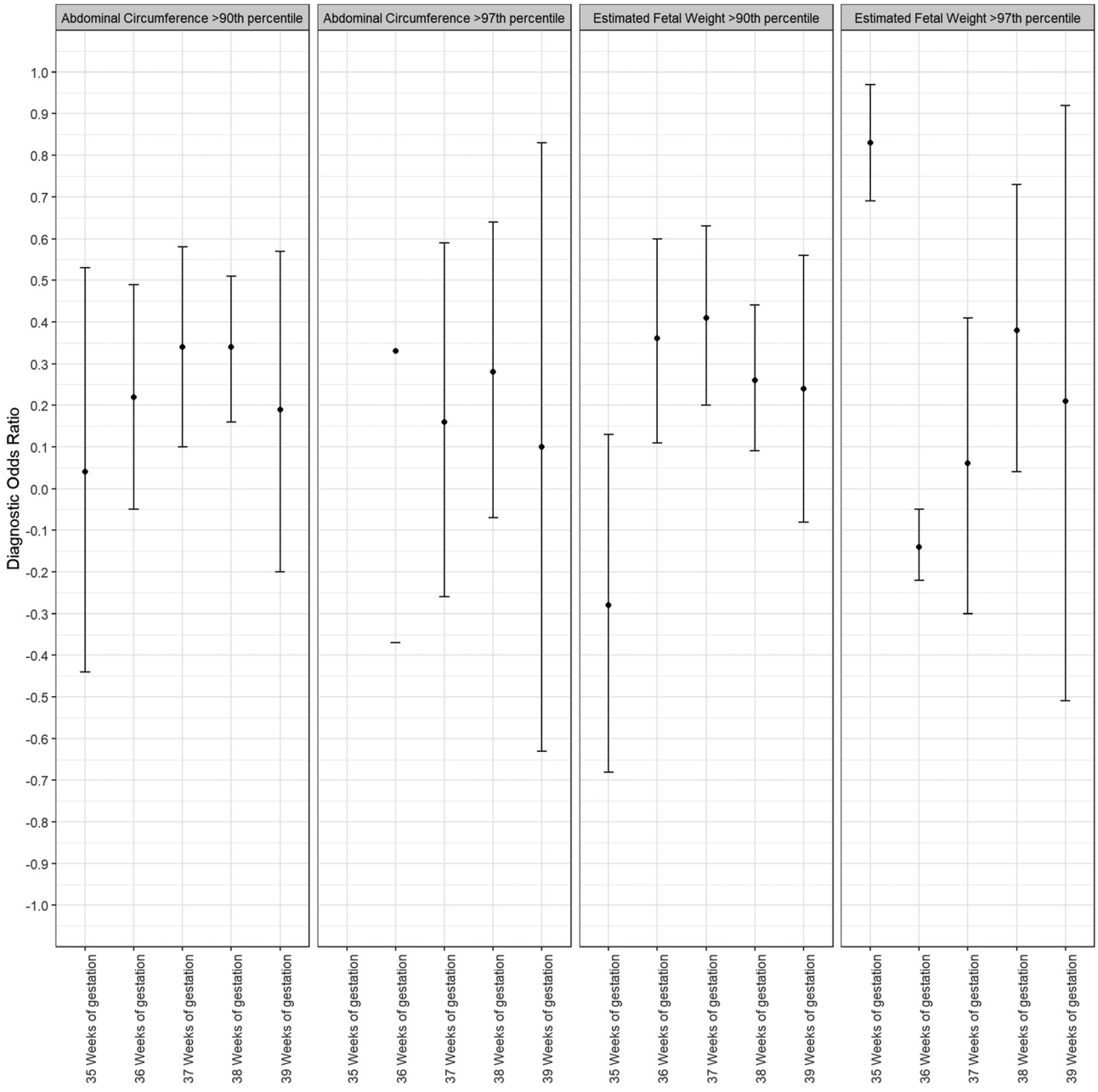

Figure 11: Diagnostic odds ratio of ultrasound of ultrasound parameters by time of screening.

complications, as illustrated by Ye [37]. Despite this innovative classification, our findings remain broadly consistent with the literature, particularly concerning diagnostic performance [8, 21], mean estimation error [5, 22, 23] and the persistent tendency to overestimate fetal weight [5–7, 38].

The longitudinal and multicenter design of this study is another strength, enabling us to include a relatively large cohort of patients over a one-year period. By not excluding women with gestational diabetes, we ensured our sample more closely resembled real-world populations, as diabetes affects a significant proportion of pregnancies (over 20 % in this study). However, the observational nature of the study limited our ability to control for certain biases, such as variability in ultrasound and SFH measurement techniques. Moreover, the absence of a central review of measurements may have slightly reduced precision, though it allowed us to evaluate performance under typical clinical conditions.

This study was part of a larger protocol investigating LGA fetus management, which explains some methodological choices. For example, the exclusion of patients with a

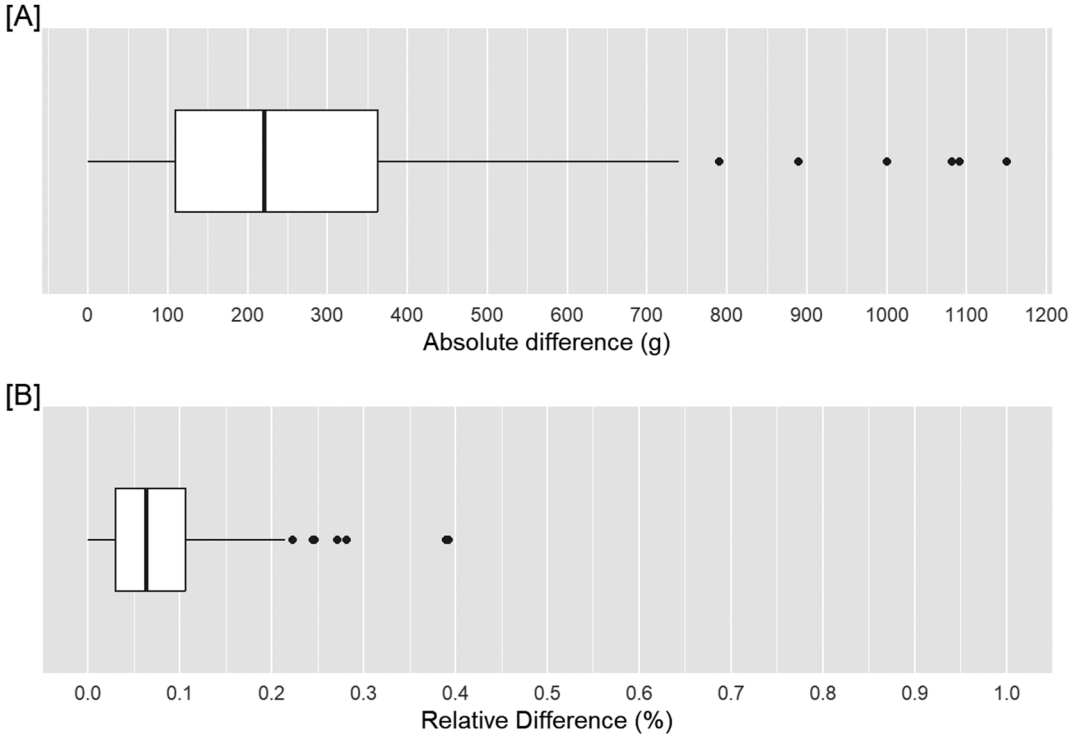

Figure 12: Boxplot of absolute (A) and relative (B) differences between measured neonatal weight and ultrasound estimated fetal weight in the week before delivery.

Table 4: Comparison of maternal characteristics and risk factors across true positive (TP), false negative (FN), false positive (FP), and true negative (TN) screening groups (n=2,217).

	Large-for-gestational age neonates			Appropriate-for-gestational age neonates		
	TP[d] n=92	FN[a] n=109	p-Value TP[d]–FN[a]	FP[b] n=179	TN[c] n=1837	p-Value FP[b]–TN[c]
Age, years, median (interquartile range)	29 (7.25)	28 (10)	0.143	30 (8)	29 (7)	0.007
BMI, kg/m^2, median (interquartile range)	27.11 (9.69)	23.37 (7.12)	**<0.001**	26.30 (7.90)	24.54 (7.55)	**<0.001**
Parity, n (%)			0.217			**0.005**
Nulliparous	38 (41.30)	45 (41.28)		63 (35.20)	834 (45.40)	
Primiparous	34 (36.96)	30 (27.52)		53 (29.61)	549 (29.89)	
Multiparous	20 (21.74)	34 (31.19)		63 (35.20)	454 (24.71)	
History of LGA fetus, n (%)	19 (20.65)	14 (12.84)	0.137	15 (8.38)	51 (2.78)	**<0.001**
History of diabetes, n (%)	12 (13.04)	13 (11.93)	0.811	16 (8.94)	65 (3.54)	**<0.001**
Gestational diabetes, n (%)	37 (40.22)	21 (19.27)	**0.001**	53 (29.61)	337 (18.35)	**<0.001**
Controlled diabetes, n (%)	22 (62.86)	13 (68.42)	0.683	29 (59.18)	233 (73.50)	**0.039**
Insulin diabetes, n (%)	20 (55.56)	10 (47.62)	0.563	21 (42.00)	124 (39.12)	0.698

[a]FN, false negative; [b]FP, false positive; [c]TN, true negative; [d]TP, true positive. Values in bold are significant p-values.

history of cesarean section was consistent with the broader protocol but may have reduced generalizability in this specific analysis. Nonetheless, this is unlikely to have significantly impacted LGA prevalence or ultrasound performance. In particular, given the very low rate of cesarean delivery for suspected macrosomia in this population at our institution, we believe this exclusion is unlikely to have significantly affected fetal weight distribution or the diagnostic performance of ultrasound.

Our findings reinforce the notion that fetal weight estimation remains highly operator-dependent, a challenge previously acknowledged in the literature. While our results corroborate prior studies demonstrating the limited accuracy of screening tools, they also provide updated insights that can

Table 5: Diagnostic performance of the combination of ultrasound growth parameter at 3rd-trimester ultrasound and clinical factor (n=2,217).

	Sensitivity	Specificity	PPV[e]	NPV[d]	DOR[b]	Youden's index	Accuracy
AC[a]≥90th percentile							
BMI≥25	0.22 [0.17–0.29]	0.96 [0.95–0.97]	0.35 [0.27–0.44]	0.93 [0.91–0.94]	6.8 [4.56–10.12]	0.18	0.89
BMI≥30	0.12 [0.08–0.18]	0.98 [0.97–0.98]	0.36 [0.25–0.48]	0.92 [0.91–0.93]	6.22 [3.72–10.38]	0.1	0.9
Nulliparous	0.12 [0.08–0.17]	0.97 [0.97–0.98]	0.32 [0.21–0.43]	0.92 [0.9–0.93]	5.12 [3.08–8.5]	0.09	0.9
Primiparous	0.13 [0.09–0.18]	0.98 [0.97–0.99]	0.39 [0.28–0.52]	0.92 [0.91–0.93]	7.34 [4.37–12.31]	0.11	0.9
Multiparous	0.11 [0.07–0.16]	0.98 [0.97–0.98]	0.33 [0.22–0.46]	0.92 [0.9–0.93]	5.51 [3.23–9.39]	0.09	0.9
History of LGA fetus	0.09 [0.05–0.14]	0.99 [0.99–1]	0.6 [0.41–0.77]	0.92 [0.9–0.93]	16.42 [7.79–34.62]	0.08	0.91
History of diabetes	0.05 [0.03–0.1]	1 [0.99–1]	0.73 [0.45–0.92]	0.91 [0.9–0.93]	29.11 [9.18–92.29]	0.05	0.91
Gestational diabetes	0.15 [0.1–0.21]	0.98 [0.97–0.98]	0.42 [0.3–0.54]	0.92 [0.91–0.93]	8.24 [5.03–13.51]	0.13	0.9
Controlled diabetes	0.1 [0.07–0.16]	0.99 [0.98–0.99]	0.49 [0.33–0.65]	0.92 [0.9–0.93]	10.57 [5.7–19.59]	0.09	0.91
EFW[c]≥90th percentile							
BMI≥25	0.23 [0.18–0.3]	0.97 [0.96–0.97]	0.41 [0.32–0.5]	0.93 [0.91–0.94]	8.61 [5.74–12.91]	0.2	0.9
BMI≥30	0.14 [0.09–0.2]	0.98 [0.97–0.99]	0.41 [0.29–0.54]	0.92 [0.91–0.93]	7.99 [4.81–13.27]	0.12	0.9
Nulliparous	0.15 [0.1–0.21]	0.98 [0.97–0.98]	0.38 [0.27–0.49]	0.92 [0.91–0.93]	6.9 [4.27–11.14]	0.12	0.9
Primiparous	0.15 [0.1–0.21]	0.98 [0.98–0.99]	0.49 [0.36–0.62]	0.92 [0.91–0.93]	11.23 [6.64–19]	0.13	0.91
Multiparous	0.07 [0.04–0.12]	0.98 [0.97–0.99]	0.28 [0.17–0.42]	0.91 [0.9–0.93]	4.2 [2.27–7.77]	0.06	0.9
History of LGA fetus	0.08 [0.05–0.13]	1 [0.99–1]	0.62 [0.41–0.8]	0.92 [0.9–0.93]	17.35 [7.76–38.78]	0.07	0.91
History of diabetes	0.04 [0.02–0.08]	1 [0.99–1]	0.53 [0.28–0.77]	0.91 [0.9–0.92]	11.77 [4.49–30.85]	0.04	0.91
Gestational diabetes	0.16 [0.11–0.22]	0.98 [0.97–0.99]	0.46 [0.34–0.59]	0.92 [0.91–0.93]	10.13 [6.15–16.67]	0.14	0.91
Controlled diabetes	0.1 [0.06–0.15]	0.99 [0.99–0.99]	0.53 [0.36–0.69]	0.92 [0.9–0.93]	12.27 [6.37–23.61]	0.09	0.91

[a]AC, abdominal circumference; [b]DOR, diagnostic odds ratio; [c]EFW, estimated fetal weight; [d]NPV, negative predictive value; [e]PPV, positive predictive value.

inform future research. From a clinical perspective, our findings highlight the limited value of combined maternal risk factors and fetal biometric thresholds as standalone screening tools for fetal macrosomia. While these combinations demonstrate excellent specificity and can therefore support the confirmation of suspected cases, their poor sensitivity significantly limits their ability to effectively rule out macrosomia. In practice, this implies that a negative screening result should not be used to reassure clinicians or guide decision-making regarding delivery planning. Instead, these tests may be more appropriately used in conjunction with other clinical findings or within multivariable predictive models. The consistently high specificity and diagnostic odds ratios associated with certain maternal risk factors – particularly prior macrosomia and diabetes – suggest that targeted screening in high-risk populations may be more clinically meaningful than universal application.

Improving LGA screening performance is critical for advancing obstetric care. Various strategies have been explored, such as adopting different growth charts, but these have not significantly enhanced predictive accuracy [39, 40]. Prescriptive approaches, including the use of Intergrowth-21 charts, have similarly failed to demonstrate clear advantages over descriptive charts [41]. Emerging technologies, such as artificial intelligence [42], novel measurement parameters [43], mobile applications [44], or MRI [45] offer potential avenues for improvement. However, their clinical applicability is hindered by high costs and substantial inter-operator variability.

Alternatively, we may need to reconsider whether substantial improvements in screening are feasible. If limitations persist, prioritizing the management of rare but severe complications – such as shoulder dystocia – through enhanced training and simulation could reduce the perceived risks associated with LGA diagnoses. This approach could also help mitigate the consequences of erroneous screening, such as unnecessary interventions or over-medicalization. Ultimately, a balanced management plan that incorporates these realities is essential for optimizing maternal and neonatal outcomes.

Conclusions

The findings of this study highlight the limitations of LGA screening and the potential impact of operator bias. No single parameter proved superior, and adding SFH measurements did not significantly enhance accuracy. These results underscore the challenges of reliable fetal weight estimation and suggest a cautious approach to LGA labeling to avoid unnecessary interventions.

Future strategies should focus on improving operator training, exploring innovative measurement techniques, and adopting management protocols that account for the inherent

imprecision of screening methods. Addressing these limitations is essential to minimizing the risks of over-medicalization while ensuring optimal outcomes for both mothers and neonates.

Research ethics: This study was conducted in accordance with the Declaration of Helsinki. This study was submitted to an IRB, the "Comité de Protection des Personnes (CPP) Ouest V – Rennes" (CNRIPH SI reference: 20.04.08.39035). They stated that this study conforms to French ethical guidelines for research without requiring ethical validation.
Informed consent: Women were informed of the hospital's participation in this study through 1) waiting room posters; 2) during their first pregnancy follow-up appointment: they were given an information note explaining the data collected, the reason for the study and the lack of impact on their follow-up. In compliance with French law concerning observational studies, women were included if they did not refuse after being informed. All women's information was de-identified and will not be shared with third parties.
Author contributions: Benjamin Birene: Writing original draft, methodology, editing, project administration, investigation, formal analysis; Alexandre Ferreir: Investigation, review; Emilie Raimond: Methodology; Olivier Graesslin: Review; Uzma Ishaque: Methodology, review, supervision; René Gabriel: Methodology, review, editing, supervision. All authors have accepted responsibility for the entire content of this manuscript and approved its submission.
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