

ULTRASOUND-BASED PREDICTION OF NEONATAL BIRTH WEIGHT AT TERM USING FETAL BIOMETRY

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Abstract

Background: Fetal weight assessment near delivery is central to obstetric risk stratification because both low birth weight and excessive fetal growth are associated with adverse maternal and neonatal outcomes. Ultrasound-based estimated fetal weight (EFW) is widely used in late pregnancy, but its clinical value depends on how closely the estimate reflects neonatal weight after birth.

Objective: To characterize the relationship between term ultrasound EFW and neonatal birth weight, with particular attention to gestational-age-specific patterns from 37 to 40 weeks.

Methods: A prospective comparative study was performed in a diagnostic ultrasound service in Islamabad, Pakistan. Pregnant women referred for late-gestation obstetric scanning were enrolled using non-probability sampling. Ultrasound examinations were performed on a MyLab 50 grayscale system with a 3-5 MHz transducer. Recorded fetal biometric variables included biparietal diameter, abdominal circumference and femur length, from which EFW was obtained. Birth weight was recorded after delivery. The planned sample size was 109, and 108 cases were included in the final analysis. Descriptive measures and t-test comparisons were used to examine EFW and birth weight overall and within gestational-age groups.

Results: The overall mean EFW was 3.3979 +/- 0.3173 kg and mean birth weight was 3.4089 +/- 0.4608 kg. The mean difference was -0.0110 kg, and the comparison was not statistically significant (p=0.838). The subgroup table included 44 women at 37 weeks, 36 at 38 weeks, 25 at 39 weeks and 3 at 40 weeks. Mean EFW versus birth weight was 3.2736 versus 3.3205 kg at 37 weeks, 3.4375 versus 3.4733 kg at 38 weeks, 3.5472 versus 3.4728 kg at 39 weeks and 3.5000 versus 3.4000 kg at 40 weeks. The comparisons at 37, 38 and 39 weeks were also non-significant.

Conclusion: At the level of group means, term ultrasound EFW closely approximated neonatal birth weight in this cohort. The findings support the

clinical usefulness of late-pregnancy sonographic biometry while also emphasizing that mean-level agreement does not quantify individual prediction error. Future work should use paired agreement methods, prespecified EFW equations and scan-to-delivery intervals to determine individual-level accuracy.

1. INTRODUCTION

Birth weight is one of the most clinically informative measurements available at the transition from intrauterine to neonatal life. Before delivery, however, the clinician must make decisions without direct access to that measurement. Decisions regarding surveillance, timing of birth, route of delivery and preparedness for neonatal complications may be influenced by whether a fetus is considered appropriately grown, growth restricted or excessively large. This makes antenatal estimation of fetal size a practical component of obstetric care rather than a purely descriptive ultrasound exercise. The clinical importance is reinforced by the association of low birth weight with prematurity and fetal growth restriction, and by the well-described maternal and neonatal complications of macrosomia, including shoulder dystocia, brachial plexus injury, birth trauma, intrapartum asphyxia and operative delivery [8,9,14]. Ultrasound provides a non-invasive method for estimating fetal size from measurable anatomic dimensions. Standard fetal biometry typically incorporates measurements such as biparietal diameter (BPD), head circumference, abdominal circumference (AC) and femur length (FL). These measurements capture complementary aspects of fetal growth. BPD and head measurements reflect cranial size, FL represents longitudinal skeletal growth, and AC is particularly sensitive to soft-tissue and hepatic growth. Mathematical equations combine selected biometric measurements to generate an estimated fetal weight. Shepard and Hadlock equations are among the most commonly cited approaches, and multiple combinations of head, abdominal and femoral measurements have been studied [10-13]. Although EFW is routinely displayed by ultrasound systems, it remains an estimate rather than a direct measurement. Error

can arise at several stages. The sonographer may not obtain an ideal imaging plane because of fetal position, maternal body habitus, placental location or reduced amniotic fluid. Caliper placement can introduce operator-dependent variation. A small measurement difference, particularly in abdominal circumference, may be amplified when incorporated into a weight equation. In addition, fetuses with similar external dimensions can have different tissue composition and therefore different true weights. These limitations explain why ultrasound can perform well at a population level while still producing clinically relevant errors in individual pregnancies. Published literature demonstrates both the usefulness and the imperfection of sonographic weight estimation. Rashid reported a mean percentage error of -1.4% with a standard deviation of 7.6% in a Bangladeshi population and concluded that ultrasound was a reliable method when a Hadlock equation based on head circumference, femur length and abdominal circumference was applied [3]. Francis and colleagues, analyzing scans performed within three days of delivery, reported that approximately 73% of term EFW values fell within $\pm 10\%$ of birth weight [5]. Ugwu and colleagues found that ultrasound estimates were within 10% of actual birth weight in 67.5% of cases and outperformed clinical estimation in their cohort [1]. These results show that ultrasound can provide clinically meaningful proximity to birth weight, but they also indicate that perfect agreement should not be expected. Other studies illustrate sources of variability. Hellmeyer and colleagues found that the central half of sonographic estimates was approximately within 200 g of actual weight depending on the reference method, while a subset of estimates differed by 500 g or more; examiner experience improved performance [4].

Peregrine and colleagues observed differing performance among clinical estimates and two sonographic formulas immediately before induction of labor, and noted that ultrasound was particularly useful for identifying fetuses at low or high weight extremes [6]. Such findings are important because clinical consequences are often concentrated at those extremes rather than near the center of the birth-weight distribution. A further issue is the timing of measurement. Fetal weight increases as pregnancy advances, and the relationship between an ultrasound estimate and subsequent birth weight depends partly on how much time elapses between the scan and delivery. A study performed at 37 weeks may be clinically interpreted differently from one performed immediately before delivery. Gestational-age-specific examination of EFW and birth weight can therefore provide a useful descriptive view of how estimates behave across the term period, even when a complete individual-level error analysis is not available. The present study prospectively evaluated the relationship between ultrasound EFW and neonatal birth weight in women scanned during late gestation. The primary objective was to describe overall mean proximity between EFW and birth weight. The secondary objective was to examine whether the pattern remained broadly similar at 37, 38, 39 and 40 weeks. This gestational-age-specific approach helps distinguish population-level bias from individual predictive precision and provides a clinically relevant description of how sonographic weight estimates behave across the term period.

2. MATERIALS AND METHODS

Study design and setting

A prospective comparative design was used. Data were collected in a diagnostic ultrasound service at a teaching hospital in Islamabad, Pakistan. The study duration was six months after approval of the research protocol. The population consisted of

pregnant women referred for obstetric ultrasound in late gestation. The analyzed cohort included observations from 37 through 40 completed weeks of gestation. The planned sample size was 109; 108 cases were present in the final analyzable statistical output.

Participants and sampling

Participants were selected by non-probability sampling from the accessible clinical population. Women referred for obstetric scanning in late pregnancy were considered for inclusion. Cases with congenital fetal anomalies and women who declined participation were excluded. The documented exclusion criteria were congenital fetal anomalies and refusal to participate. Because the purpose was to compare ultrasound-derived fetal weight with the subsequently measured neonatal weight, only cases with both an EFW value and a recorded birth weight were represented in the comparative analysis.

Ultrasound examination

Ultrasound was performed using a MyLab 50 grayscale ultrasound system with a transducer frequency range of 3.0-5.0 MHz. Fetal biometric variables recorded in the study included BPD, AC and FL. BPD represents the transverse dimension of the fetal head between the parietal bones; AC is measured in a standard transverse abdominal plane and is a major contributor to fetal weight estimation; FL reflects longitudinal skeletal growth. These measurements were used by the ultrasound system to obtain EFW. The ultrasound system generated EFW from the recorded biometric measurements. Although Shepard and Hadlock equations are commonly used for sonographic fetal-weight estimation, the specific embedded equation used for these examinations was not documented; therefore, formula-specific performance is not claimed.

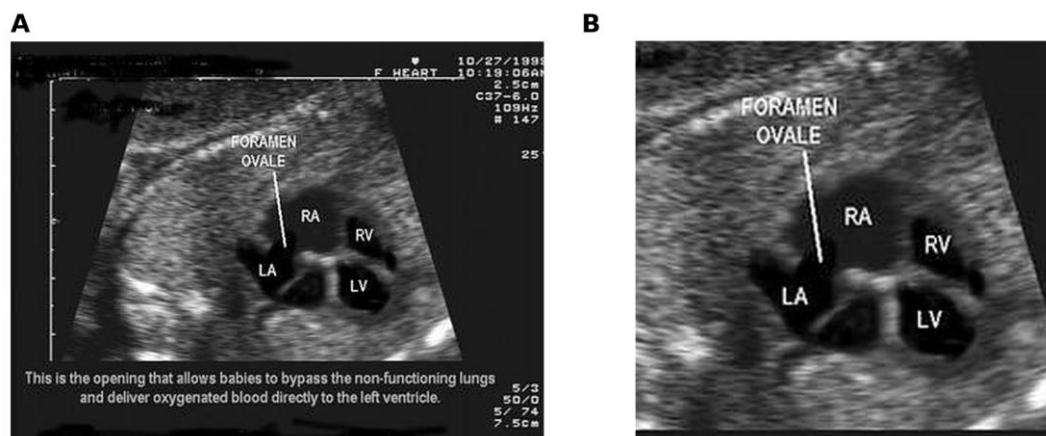


Figure 1. Representative obstetric ultrasound views: (A) full fetal cardiac image and (B) enlarged view of the cardiac region. The image is illustrative and was not used as a separate quantitative outcome.

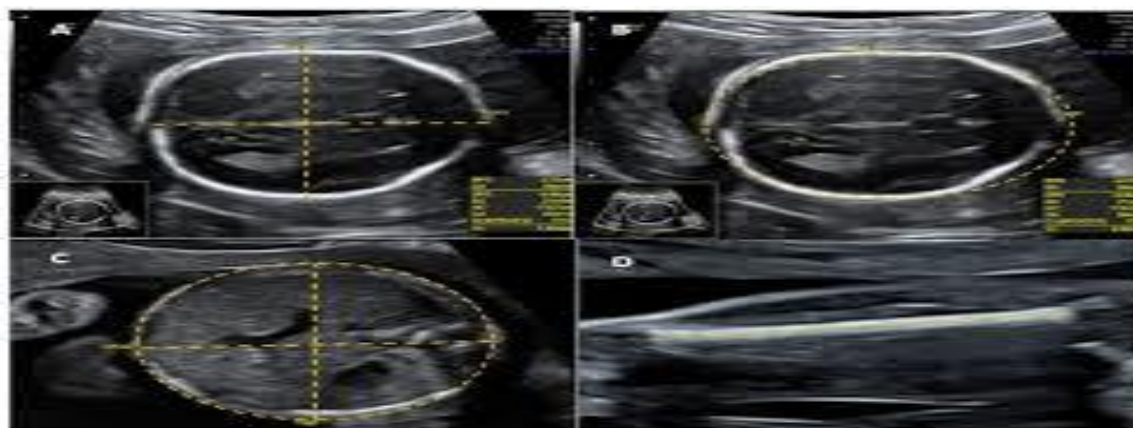


Figure 2. Fetal head biometric landmarks relevant to biparietal diameter measurement, shown as an educational anatomical reference.

Birth-weight assessment and outcome definition
The primary outcome was neonatal birth weight measured after delivery. The principal comparative variable was the difference between ultrasound EFW and actual birth weight. EFW and birth weight were summarized overall and within gestational-age groups. The complete scan-to-delivery interval was not available for analysis; therefore, no modeled fetal-growth adjustment was applied between the ultrasound examination and delivery.

Data management and statistical analysis

Data were entered in Microsoft Excel and analyzed with SPSS version 21.0. Descriptive statistics

included sample size, mean, standard deviation, range, minimum and maximum where available. Mean EFW and birth weight were compared using the t-test framework reported in the statistical analysis, with a two-sided p value below 0.05 considered statistically significant. The statistical output used an independent-samples format even though EFW and birth weight originated from the same pregnancies. Because participant-level paired observations were not retained for reanalysis, the reported inferential results are presented as generated, and greater emphasis is placed on the descriptive proximity of the mean values.

Ethical considerations

Ethical approval was obtained before initiation of the study. Written informed consent was obtained from participants or their guardians as applicable. Participants were informed about the purpose of the study and their right to withdraw. Identifying information was not intended for publication, and collected information was kept confidential. The ultrasound images presented in this manuscript are illustrative and are shown without patient-identifying information.

3. RESULTS

The final analysis included 108 pregnancies. The gestational-age subgroup table accounted for the entire analytic sample: 44 examinations were recorded at 37 weeks, 36 at 38 weeks, 25 at 39 weeks and 3 at 40 weeks. Thus, most observations were obtained between 37 and 39 weeks, while the 40-week subgroup was too small for a stable inferential comparison.

Table 1. Overall descriptive comparison of ultrasound EFW and neonatal birth weight

Measure	N	Mean (kg)	SD (kg)	Minimum (kg)	Maximum (kg)
Ultrasound EFW	108	3.3979	0.3173	2.50	4.05
Birth weight	108	3.4089	0.4608	2.00	4.50

Across all 108 cases, mean ultrasound EFW was 3.3979 kg with a standard deviation of 0.3173 kg. Mean neonatal birth weight was 3.4089 kg with a standard deviation of 0.4608 kg. The difference between the two group means was approximately 0.011 kg, or 11 g, with EFW slightly lower than birth weight. The mean difference in the t-test analysis was -0.01102 kg and the two-sided p value was 0.838. The 95% confidence interval for the mean difference in the equal-variance row extended from approximately -0.117 to 0.095 kg. At the level of the overall mean, therefore, there was little evidence of systematic overestimation or underestimation.

Gestational-age-specific results showed a similar pattern of small mean differences. At 37 weeks,

mean EFW was 3.2736 kg and mean birth weight was 3.3205 kg, corresponding to an EFW-minus-birth-weight difference of approximately -0.0469 kg. The p value was 0.627. At 38 weeks, mean EFW was 3.4375 kg and mean birth weight was 3.4733 kg, a difference of approximately -0.0358 kg; the p value was 0.620. At 39 weeks, mean EFW was 3.5472 kg compared with mean birth weight of 3.4728 kg, so the direction shifted toward modest overestimation by approximately 0.0744 kg; the p value was 0.510. At 40 weeks, the three recorded cases had a mean EFW of 3.5000 kg and mean birth weight of 3.4000 kg. No stable inferential conclusion should be drawn from this subgroup because of its very small size.

Table 2. Gestational-age-specific mean estimated fetal weight and birth weight

Gestational age	N	Mean EFW (kg)	Mean birth weight (kg)	Difference EFW-BW (kg)	p value
37 weeks	44	3.2736	3.3205	-0.0469	0.627
38 weeks	36	3.4375	3.4733	-0.0358	0.620
39 weeks	25	3.5472	3.4728	+0.0744	0.510
40 weeks	3	3.5000	3.4000	+0.1000	Not tested

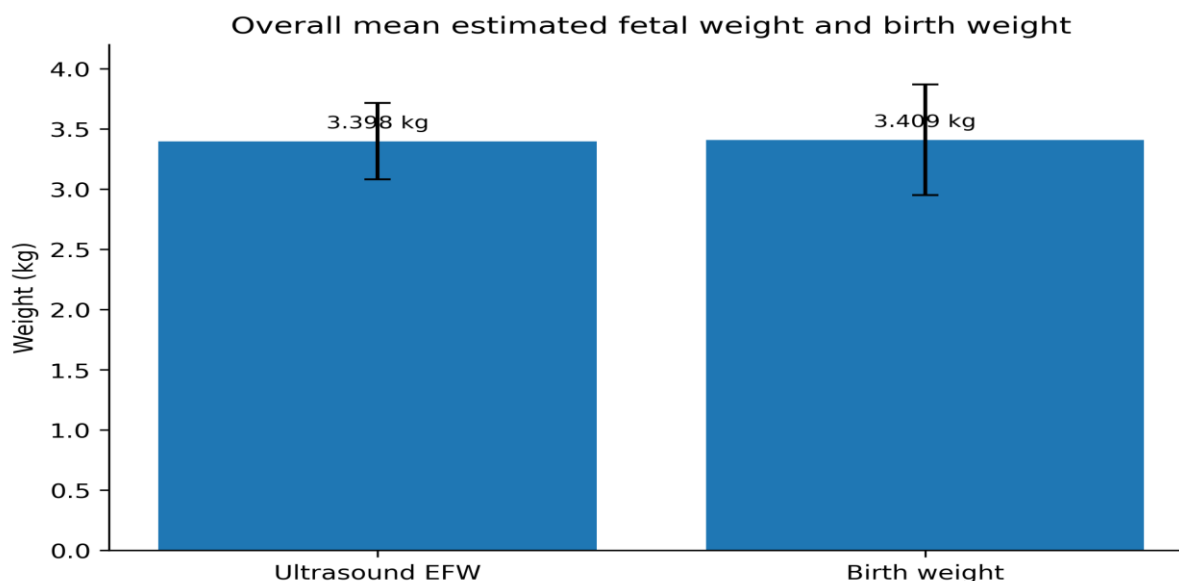


Figure 3. Overall mean ultrasound estimated fetal weight and neonatal birth weight. Error bars show the reported standard deviations.

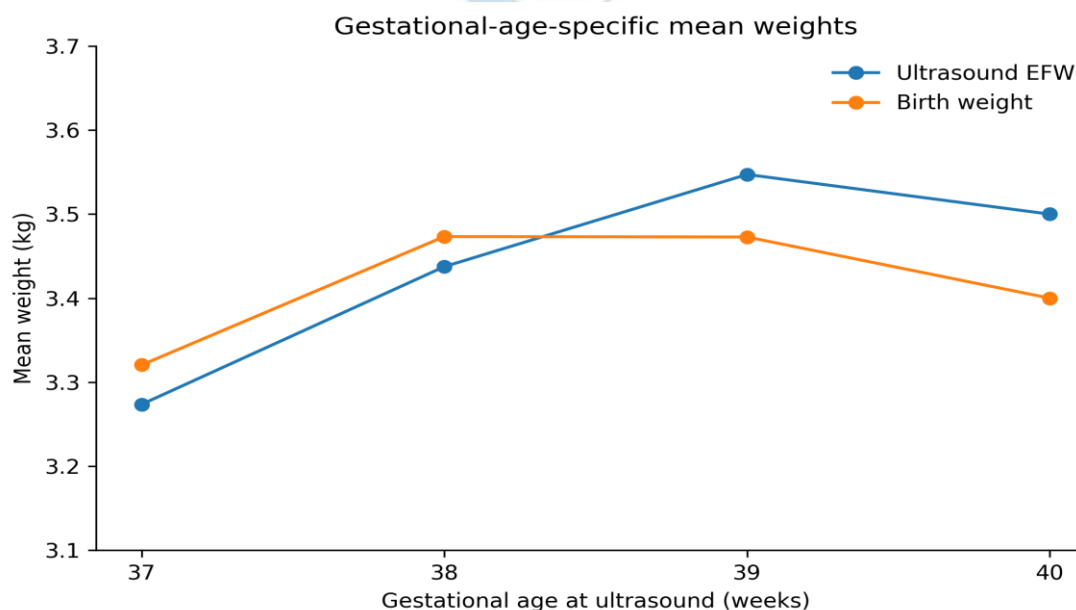


Figure 4. Mean ultrasound EFW and neonatal birth weight by gestational age. The 40-week subgroup contained only three observations and should be interpreted descriptively.

The descriptive pattern is clinically notable for two reasons. First, the mean values were close overall and remained within roughly 0.10 kg of one

another in each gestational-age subgroup. Second, the direction of the difference was not constant across gestational age: EFW was slightly lower than birth weight at 37 and 38 weeks but slightly higher

at 39 and 40 weeks. This variation argues against describing the method as uniformly biased in one direction on the basis of the summary data.

Descriptive statistics were also generated for BPD, AC and FL. However, several entries in the BPD and FL summary output were internally implausible for fetal biometry, including extreme

values that strongly suggest data-entry or coding problems. Those implausible biometric summary values were excluded from clinical interpretation. The EFW and birth-weight values, which were internally coherent across the overall and gestational-age tables, form the basis of the present analysis.

Table 3. T-test comparisons of ultrasound EFW and neonatal birth weight

Comparison	Mean difference (kg)	t	df	p value	95% CI (kg)
Overall	-0.01102	-0.205	214	0.838	-0.117 to 0.095
37 weeks	-0.04682	-0.488	86	0.627	-0.237 to 0.144
38 weeks	-0.03583	-0.498	70	0.620	-0.179 to 0.108
39 weeks	+0.07440	0.663	48	0.510	-0.151 to 0.300

Note: Because EFW and birth weight arise from the same pregnancies, paired-data methods would be preferable if participant-level observations are available for reanalysis.

4. DISCUSSION

This prospective cohort demonstrates close proximity between mean term ultrasound EFW and mean neonatal birth weight. The overall difference between the two means was only about 11 g, and the subgroup mean differences at 37, 38 and 39 weeks were also small. These findings support the practical value of ultrasound biometry as a population-level indicator of fetal size near term. At the same time, the summary results do not justify the stronger claim that every individual fetus was estimated with high precision. That distinction is central to an appropriate interpretation of fetal-weight studies. A method can have little average bias while still producing wide individual errors. For example, overestimation in some fetuses and underestimation in others can cancel one another when the mean is calculated. The present study provides strong descriptive evidence that the cohort mean EFW was not materially displaced from mean birth weight, but summary means alone cannot provide the mean absolute percentage error, the proportion of estimates within $\pm 10\%$ of birth weight, or Bland-Altman limits of agreement. Those measures require

participant-level paired EFW and birth-weight data. The absence of such metrics should therefore be viewed as a limitation of the analysis rather than evidence that individual errors were negligible. The overall pattern is nevertheless consistent with published literature. Rashid's prospective study from Bangladesh included 73 infants and reported a mean relative error of -1.4% with a standard deviation of 7.6% , supporting the clinical reliability of ultrasound EFW using a Hadlock-based approach [3]. The small average difference in the present cohort similarly suggests limited systematic bias at the group level. However, Rashid's percentage-error analysis provided information about individual variability that could not be calculated in the present analysis because participant-level paired data were not retained. Francis and colleagues examined ultrasound scans performed within three days of delivery and found that 73% of term EFW values were within $\pm 10\%$ of subsequent birth weight [5]. Their findings are particularly relevant because the short scan-to-delivery interval reduces the amount of true fetal growth occurring between estimation and birth. In the present study, the scan-to-delivery interval was not available for analysis. This may partially explain why gestational-age-specific differences

cannot be interpreted simply as measurement error. A fetus scanned at 37 weeks and delivered several days later would be expected to gain weight before birth, whereas a scan performed immediately before delivery would be more directly comparable with the measured neonatal weight.

Ugwu and colleagues compared clinical and sonographic methods at term and observed a strong positive correlation of actual birth weight with both methods, but ultrasound estimates were more frequently within 10% of actual weight than clinical estimates, particularly among macrosomic fetuses [1]. Their results reinforce a major clinical advantage of ultrasound: it provides a standardized anatomic basis for weight estimation when bedside palpation is uncertain. The present cohort does not include a clinical-estimation comparator, but the close mean EFW and birth-weight values are compatible with ultrasound being a useful quantitative adjunct to obstetric examination.

At the same time, not all published studies show uniformly superior performance for every ultrasound formula or clinical circumstance. Peregrine and colleagues evaluated women immediately before induction of labor and compared estimates made by doctors, the women themselves, and two ultrasound equations [6]. The proportion of estimates within 10% of birth weight varied substantially across methods. They also found ultrasound particularly useful in predicting low- and high-birth-weight fetuses. This is clinically important because the consequences of error are asymmetric: an error around an average 3.3-kg fetus may have little management impact, whereas misclassification around thresholds for growth restriction or macrosomia may influence induction, cesarean planning, neonatal preparedness and counseling. Examiner experience is another plausible contributor to error. Hellmeyer and colleagues reported that experienced sonographers tended to estimate birth weight more accurately than less experienced clinicians and that a subset of estimates differed from actual birth weight by 500 g or more [4]. Sonographic biometry depends on acquisition of standardized planes and careful caliper placement.

BPD requires a reproducible axial head plane; AC requires a correct transverse abdominal level; and FL requires visualization of the ossified diaphysis without including epiphyses. Measurement quality can be affected by fetal position, maternal habitus, placentation, oligohydramnios and late-gestation crowding, all of which were recognized as limiting factors in the study background. Among biometric measurements, abdominal circumference deserves particular attention because it contributes strongly to fetal weight equations and may vary with fetal nutritional status. Small differences in the measured abdominal perimeter can produce meaningful changes in calculated weight. Femur length provides complementary information on skeletal growth, while cranial measurements stabilize the overall estimate. The study's ultrasound protocol recorded BPD, AC and FL, but some biometric summary outputs contained implausible values. For that reason, this manuscript deliberately avoids drawing conclusions from those specific descriptive measurements and focuses on the internally consistent EFW and birth-weight results. The gestational-age-specific pattern is also informative. At 37 and 38 weeks, the mean ultrasound estimate was modestly lower than mean birth weight. This direction is compatible with at least two non-exclusive explanations: true fetal growth between the scan and delivery, and mild underestimation by the biometric algorithm. At 39 weeks, however, the direction reversed and EFW modestly exceeded birth weight. Because the exact scan-to-delivery interval was unavailable and the subgroup sample sizes differed, the pattern cannot be attributed to a single mechanism. The most defensible interpretation is that no consistent directional bias is evident across the term period in these summary data. The 40-week subgroup illustrates why sample size matters. Only three cases were represented, with mean EFW of 3.50 kg and mean birth weight of 3.40 kg. A 100-g difference in such a small group is highly unstable and could change markedly with one additional observation. It should not be generalized to all 40-week pregnancies. In contrast, the 37-week and 38-week groups contained 44 and 36 observations

respectively and therefore provide a more stable description of the cohort's central tendency. Clinically, the findings support using ultrasound EFW as one component of decision-making rather than as an isolated determinant of delivery strategy. An EFW close to 3.4 kg in a term pregnancy may reassure the clinician that fetal size is broadly within an expected range, but management should continue to integrate gestational age, maternal history, diabetes status if present, pelvic assessment, fetal presentation, growth trajectory, amniotic fluid, Doppler findings when indicated and the overall obstetric context. The study itself was designed around weight comparison and did not collect all of these modifiers, so no management algorithm should be inferred directly from these results. The distinction between detecting fetal growth abnormalities and predicting exact birth weight is also relevant. Ultrasound can be clinically valuable even when its numeric estimate is not exact to the gram. In practice, the purpose is often to identify a fetus that is unexpectedly small or large, to monitor growth over time, or to trigger closer surveillance. Francis et al. emphasized the value of term ultrasound in identifying pregnancies at risk for growth restriction [5]. Similarly, the literature on macrosomia highlights the substantial maternal and neonatal risks associated with excessive fetal size [9]. Thus, the utility of EFW is partly categorical and risk-oriented, not merely numerical. Several strengths of the present study should be recognized. It was prospective, used a consistent ultrasound service and equipment platform, and directly linked antenatal EFW with neonatal birth weight. The overall analytic sample of 108 provides a useful local clinical cohort, and the gestational-age subgrouping offers more detail than a single pooled mean. Ethical approval, informed consent and confidentiality procedures were documented. The study also reflects real-world practice in a resource-constrained clinical environment, which increases its relevance to settings where ultrasound is an important but not unlimited resource. The limitations are equally important. First, the study used non-probability sampling at a single clinical site, limiting

generalizability. Second, the exact EFW equation used by the ultrasound system was not documented. Because different formulas can perform differently, this prevents formula-specific conclusions. Third, the scan-to-delivery interval was not documented, making it impossible to separate measurement error from true fetal growth occurring after scanning. Fourth, the final analysis retained summary statistics rather than the raw paired observations needed for individual-level error metrics, correlation analysis, Bland-Altman assessment or recalculation with a paired statistical test. Fifth, the statistical output used an independent-samples t-test framework for measurements that arise from the same pregnancies; without raw data, that analysis cannot be corrected retrospectively. Sixth, several BPD and FL summary values were internally implausible, suggesting data-entry problems in some biometric fields. These issues do not invalidate the observed proximity of the EFW and birth-weight means, but they require restraint in claims about precision. A future study could substantially strengthen the evidence with relatively simple design improvements. The EFW equation should be prespecified, and every scan should record the exact date and time relative to delivery. Raw paired EFW and birth weight should be retained so that signed error, absolute error, percentage error, absolute percentage error, correlation and Bland-Altman limits can be calculated. Accuracy should also be stratified by clinically important birth-weight categories, such as low birth weight, normal weight and macrosomia, because average performance can conceal larger errors at the extremes. Recording maternal body mass index, parity, diabetes, fetal presentation, placental location, amniotic fluid and sonographer experience would allow assessment of factors that may influence error. Such an approach would convert the encouraging mean-level agreement seen here into a more complete evaluation of clinical predictive performance. Despite these limitations, the study provides a coherent message. In this cohort, term ultrasound biometry generated an average fetal weight that was very close to the average weight

measured after birth, and this proximity was broadly maintained from 37 to 39 weeks. The findings therefore support continued use of ultrasound EFW as a practical quantitative tool in late pregnancy, provided that clinicians recognize the difference between population-level agreement and individual certainty. That balanced interpretation is more clinically useful than labeling ultrasound either perfectly accurate or unreliable.

5. CONCLUSION

Term ultrasound biometry in this prospective cohort produced an overall mean EFW of 3.3979 kg compared with a mean neonatal birth weight of 3.4089 kg, a difference of approximately 11 g. Mean values were also close within the 37-, 38- and 39-week subgroups, and the statistical comparisons did not show significant differences. These findings indicate little systematic mean-level bias in the study population. The results should not be interpreted as proof of exact individual prediction because paired raw observations were not retained for absolute percentage error or limits-of-agreement analysis. Within those constraints, ultrasound EFW remains a clinically useful estimate of fetal size near term and can support obstetric assessment when interpreted alongside the complete clinical picture. Future prospective work should preserve paired data, specify the EFW equation and document scan-to-delivery timing so that individual predictive accuracy can be quantified more rigorously.

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