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## ARTICLE

### The evaluation of gestational age concerning placental thickness and fetal parameters using ultrasonography

 Kamlesh Kumar Shukla<sup>1\*</sup>,  Arvind Kumar Jha<sup>2</sup>,  Kanhaiya Jee<sup>3</sup>

<sup>1</sup>Department of Mathematics, Jaypee Institute of Information Technology, Noida, India.

<sup>2</sup>Department of Anatomy, Sri Krishna Medical College, Muzaffarpur, India.

<sup>3</sup>Dr. KNS Memorial Institute of Medical Sciences, Barabanki, India.

\*Corresponding author. Email: [kkshukla22@gmail.com](mailto:kkshukla22@gmail.com)

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#### Abstract

The ultrasound parameters are very important factors for the estimation of gestational age (GS) decreases as pregnancy advances in age. Therefore, it is essential to reconnoiter other parameters that may complement the established fetal biometric parameters in predicting GS, especially in late pregnancy. The main objective of this study is to determine the relationship between GS and sonographic placental thickness (PL) as well as fetal parameters for the second (21-30 weeks) and third trimesters (31-40 weeks) using regression analysis. The mean scores for PL, GS, and weight of fetal were found  $2.56 \pm 0.38$  cm,  $165.15 \pm 15.60$  days and  $654.31 \pm 266.68$  gm respectively for 21-30 weeks. Similarly mean scores were found to correspond to fetal parameters for 31-40 weeks. The relationship between GA (Y) in days and PT & BPD in cm. In the 21-30 weeks,

$GS_{21-30weeks} = 146.36 + 7.07PL_{21-30weeks}$  and  $GS_{21-30weeks} = 74.03 + 15.8BPD_{21-30weeks}$ . The relationship between GS and fetal parameters (BPD, AC, FL, etc.) are obtained as follows:

$GS_{21-30weeks} = 124.96 + 1.49BPD - 0.34HC + 0.54AC - 0.61FL - 1.2PL + 0.05Weight$

Gestational age has been estimated using two regression lines, first using three variables and second using all fetal parameters. It has been observed that Gestational age can be estimated accurately using all fetal parameters for both periods (21-30 & 31-40 weeks).

**Keywords:** Gestational Age; Femur length, Biparietal diameter, Head circumference.

## 1. Introduction

In a past study, it was observed that ultrasonography is an effective way of dating pregnancy (Rudy, 2000). Gestational age was the first ultrasound biometric parameter to be used to estimate GS. Later stage many researchers were used to estimate (GS) Gestational age (Robinson, 1973). The use of other parameters such as head circumference (HC), abdominal circumference (AC), femur length (FL), and biparietal diameter (BPD). Fetal biometric parameters such as FL, BPD, HC, and AC are normally

used to evaluate GS in the second and third trimesters. Conflicting values of GA are sometimes obtained when using most of these parameters. The AC was measured just below the lower fetal ribs marked by the presence of a short length of the umbilical vein running through the fetal liver and the stomach bubble (Hoddick *et al.*, 1985). The placenta was localized in a longitudinal section and its thickness was measured at the point of the umbilical cord insertion (Weerakkody, 2001).

Moreover, the correctness of these parameters decreases as pregnancy advances in age (Karki, 2006). Hence, there is a need to explore other parameters that may complement the established fetal biometric parameters in predicting Gestational Age (GS), especially as pregnancy advances to the third trimester. The placenta has been noted to increase as pregnancy advances in age. In most of the studies, it was mentioned that GS can be estimated using Placenta thickness (PL), however almost all fetal parameters were explored and applied to calculate GS in this study. In this sense, Regression models can be used to investigate the relationship between a dependent variable and one or more independent (or explanatory) variables. It is often used to predict values of the dependent variable based on known or predicted values of the independent variables (Batista and Prativiera, 2024).

The main objective of the present study is to fit linear regression models for estimating GS using fetal parameters such as BPD, HC, AC, FL, PL, and Weight. It has also been compared with models using PL and a combined approach of all fetal parameters to assess the superiority of models. The accuracy of models is checked using residual plots, and the significance of the parameters.

## 2. Material and Methods

This study was carried out at the departments of Anatomy and Radiology, Santosh Medical College and Hospital, Ghaziabad, located in the NCR Region/Delhi capital of India. After agreeing with written consent, 100 pregnant women (20-40 weeks) were selected. One of the authors of this paper has collected the data to complete this study. All the subjects were healthy at the time of the study. Their records indicated none of them was anemic. Patients with pregnancy-induced hypertension, diabetes mellitus, previous history of intrauterine growth restriction, congenital malformations, and multiple gestations were excluded from the study. Patients who consume alcoholic beverages or smoke tobacco were also excluded.

Ultrasound machine GE Voluson E6 with convex probe 3-5 Mhz frequency was used, and placental thickness was measured in Antero-posterior dimension.

The PT (Placenta thickness) was obtained by measuring the anteroposterior diameter of the placenta at the level/point of insertion of the umbilical cord (Mital *et al.*, 2002; Hanretty, 2003), as shown in Figure 1. Fetal parameters, including FL, BPD, HC, and AC, were also measured according to their standardized techniques, and all of them were used to estimate the GS (Gestational Age).

**Statistical Analysis:** R-software (4.2) and SPSS-26 version have been used to analyze the data. Descriptive statistics for the 21-30 and 31-40 weeks of gestation period have been explained using fetal parameters. Regression analyses have been applied to determine the relationship between gestational age (GS) and placenta thickness (PL). Other fetal parameters were also included as independent variables for both periods (21-30 and 31-40 weeks). The above hypothesis is tested at a 5% level of significance.

### Hypothesis:

1. There is a significant relationship between gestational age and placental thickness for both periods (21-30 & 31-40 weeks)
2. There is a significant association between gestational age and other fetal parameters for both periods.



**Figure 1.** Sonogram showing placenta for 30-40 weeks of gestational age.

### 3. Results

In this section, Statistics of fetal parameters have been derived and presented. Regression analyses have been applied to know the relation between GS and PL as well as other fetal parameters.

**Table 1.** Descriptive statistics of fetal parameters for gestational age 21-30 weeks

| Parameters | N   | Range | Minimum | Maximum | Mean   | Std. Deviation |
|------------|-----|-------|---------|---------|--------|----------------|
| BPD        | 100 | 3.9   | 4.2     | 8.1     | 5.757  | .7116          |
| HC         | 100 | 12.4  | 17.4    | 29.8    | 22.033 | 3.0291         |
| AC         | 100 | 12.8  | 14.3    | 27.1    | 19.204 | 3.1768         |
| FL         | 100 | 4.7   | 2.1     | 6.8     | 4.317  | .9017          |
| GS         | 100 | 66    | 147     | 213     | 165.15 | 15.603         |
| PL         | 100 | 1.80  | 2.00    | 3.70    | 2.5662 | .37720         |
| Weight     | 100 | 1215  | 357     | 1572    | 654.31 | 266.678        |

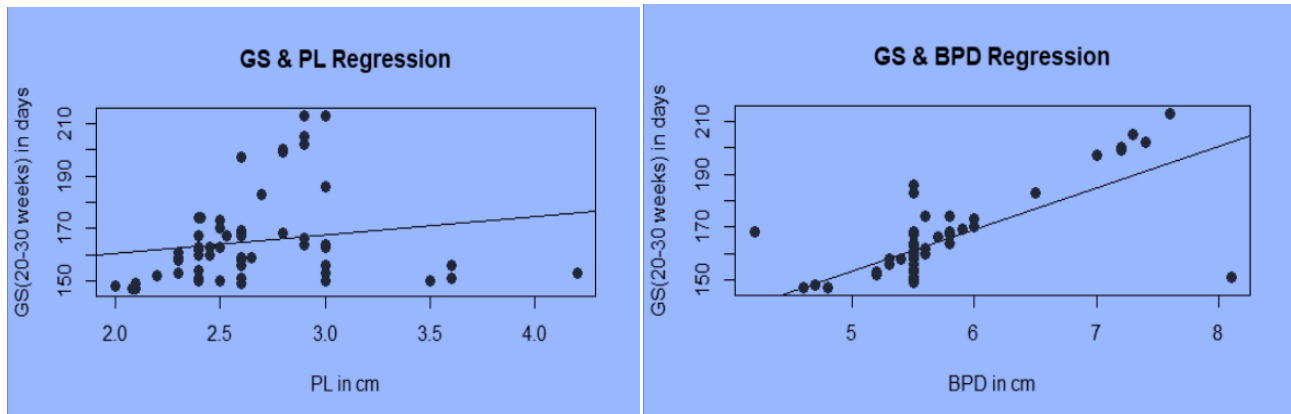
Table 1 indicates descriptive statistics of fetal parameters for gestational age 21-30 weeks. Maximum and Mean scores were 8.1cm, 29.8cm, 27.1cm, 6.8cm, 213cm, 3.70cm and 1572gm, and 5.7cm, 22.03cm, 19.2cm, 4.3cm, 165.15cm, 2.56 cm, and 654.31gm respectively for BPD, HC, AC, FL, GS, PL and weight respectively. For corresponding fetal parameters, standard deviations were found to be 0.7116cm, 3.02cm, 3.1768cm, 0.9017cm, 15.60cm, 0.37720cm, and 266.68 gm, respectively.

**Table 2.** Descriptive statistics of fetal parameters for gestational age (31-40 weeks)

|        | N   | Range | Minimum | Maximum | Mean    | Std. Deviation |
|--------|-----|-------|---------|---------|---------|----------------|
| BPD    | 100 | 2.2   | 7.7     | 9.9     | 8.569   | .5041          |
| HC     | 100 | 8.0   | 27.2    | 35.2    | 31.362  | 1.5070         |
| AC     | 100 | 10.1  | 26.3    | 36.4    | 30.908  | 1.8658         |
| FL     | 100 | 1.9   | 5.9     | 7.8     | 6.773   | .4510          |
| GS     | 100 | 66    | 218     | 284     | 246.64  | 12.395         |
| PL     | 100 | 1.20  | 2.60    | 3.80    | 3.3290  | .17042         |
| Weight | 100 | 2446  | 1655    | 4101    | 2582.56 | 453.353        |

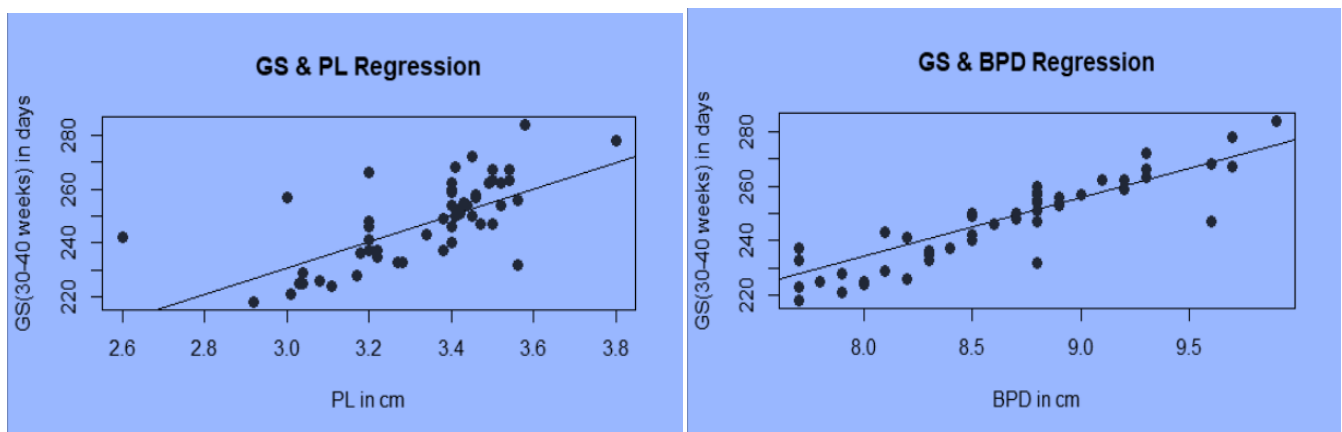
Table 2 indicates descriptive statistics for gestational age 30-40 weeks. Mean scores were 8.56cm, 31.362cm, 30.908cm, 6.773cm, 246.64cm, 3.33cm, and 2582.56 gm for BPD, HC, AC, FL, GS, and PL,

and weight, respectively. For corresponding fetal parameters, standard deviations were found to be 0.5041cm, 1.5070cm, 1.8658cm, 0.4510cm, 12.395cm, 0.1704cm, and 453.35 gm, respectively.



**Figure 2.** Regression line between GS and PL & BPD for 20-30 weeks.

Figure 2 shows the regression line between (GS) Gestational Age and Placenta thickness (PL) & biparietal diameter (BPD). It was observed that there is a good relation between GS and BPD, as well as PL, however very good relation was observed between GS and BPD in comparison to the relationship between GS and PL.



**Figure 3.** Regression line between GS and PL & BPD for 30-40 weeks.

Figure 3 shows the regression line between (GS) Gestational Age and Placenta thickness (PL) & biparietal diameter (BPD) for 30-40 weeks of Gestational age. It was found good relation between GS and BPD as well as PL, however very good linear relation was observed between GS and BPD, comparatively the relationship between GS and PL.

### Regression Models

Regression equations 1, 2,3,4,5, and 6 represent about association among GS and fetal parameters (BPD, PL, HC, AC, FL) as well as fetal weights of selected samples for both gestational periods (21-30, 31-40 weeks).

$$\text{Model 1: } GS_{21-30weeks} = a_1 + b_1 PL_{21-30weeks} \quad (1)$$

$$\text{Model 2: } GS_{21-30weeks} = a_2 + b_2 BPD_{21-30weeks} \quad (2)$$

$$\text{Model 3: } GS_{31-40weeks} = a_3 + b_3 PL_{31-40weeks} \quad (3)$$

$$\text{Model 4: } GS_{31-40weeks} = a_4 + b_4 BPD_{31-40weeks} \quad (4)$$

$$\text{Model 5: } GS_{21-30weeks} = \beta_0 + \beta_1 BPD + \beta_2 HC + \beta_3 AC + \beta_4 FL + \beta_5 PL + \beta_6 Weight \quad (5)$$

$$\text{Model 6: } GS_{31-40weeks} = \delta_0 + \delta_1 BPD + \delta_2 HC + \delta_3 AC + \delta_4 FL + \delta_5 PL + \delta_6 Weight \quad (6)$$

Where  $GS_{21-30weeks}$  – Gestational Age for 21-30 weeks ,

$GS_{31-40weeks}$  - Gestational Age for 31-40 weeks

$PL_{21-30weeks}$  \_ Gestational Age for 21-30 weeks

$PL_{31-40weeks}$  - Placenta thickness for 31-40 weeks

HC, BPD, AC, FL, PL are fetal parameters in cm. for 21-30 and 31-40 weeks

Fetus weights in grams

$a_1, a_2, a_3, a_4, b_1, b_2, b_3, b_4$ , and

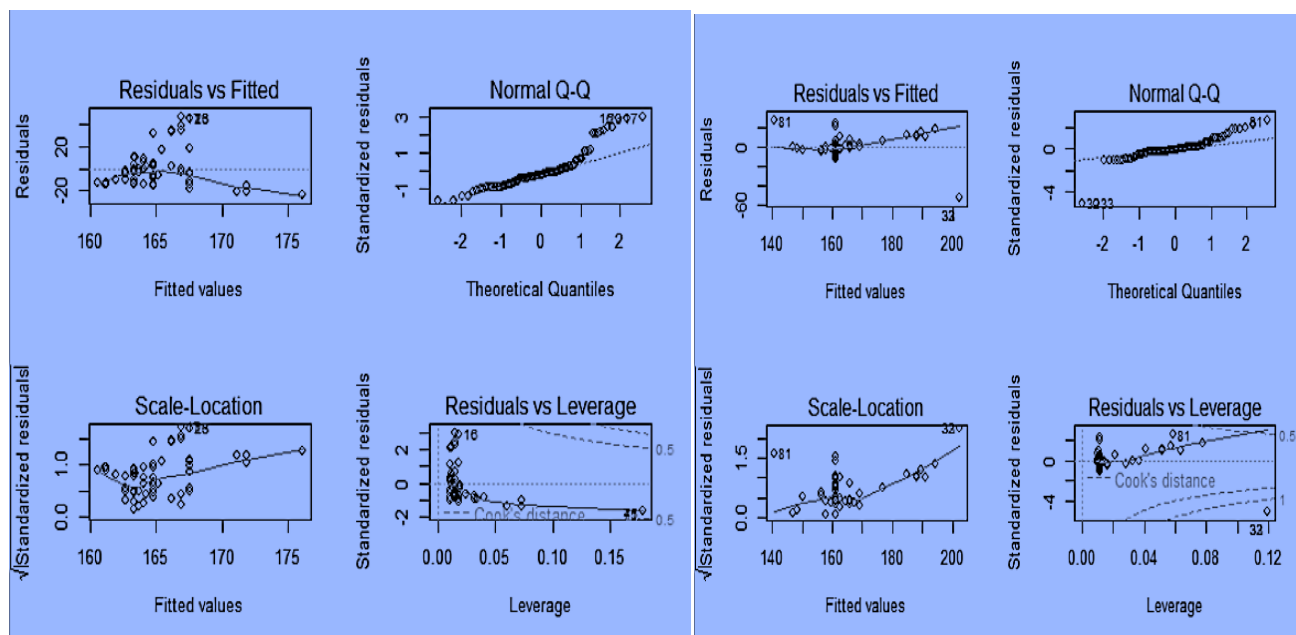
$\beta_0, \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6$ , and  $\delta_0, \delta_1, \delta_2, \delta_3, \delta_4, \delta_5, \delta_6$  are constants.

**Table 3.** Regression model summary between GS versus PL and BPD for (21-30 & 31-40 weeks)

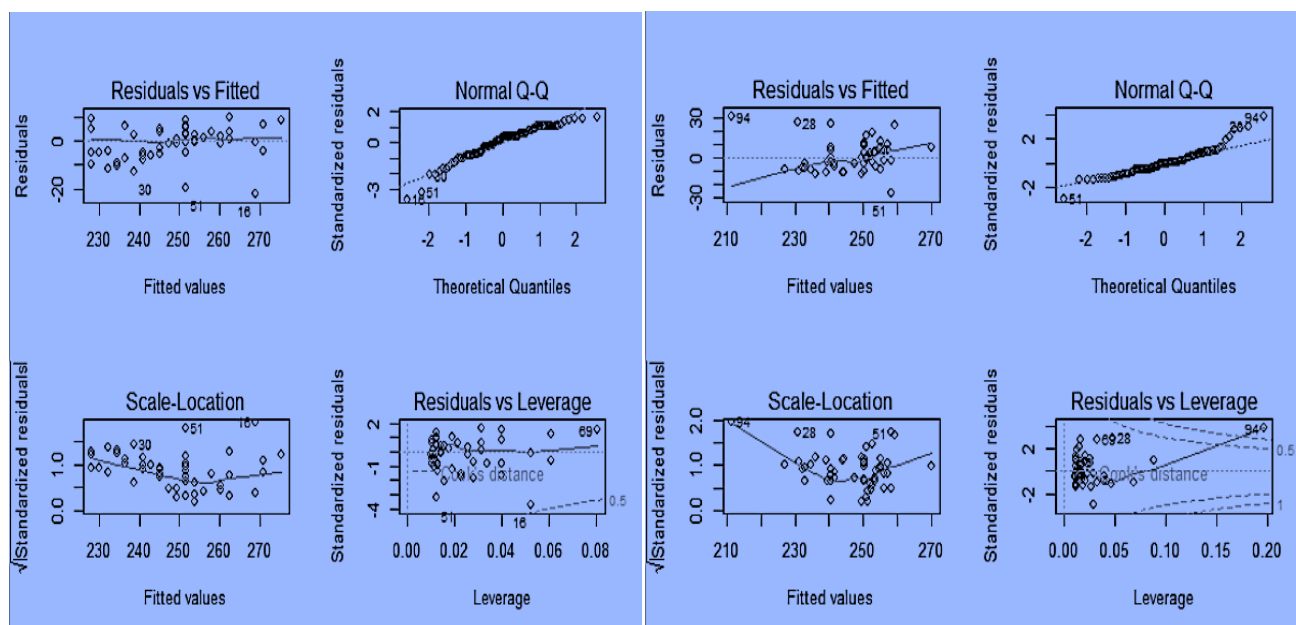
| Gestational Age (GS) | Model   | Model Summary <sup>(y)</sup> |                     | Coefficients                  |               |
|----------------------|---------|------------------------------|---------------------|-------------------------------|---------------|
|                      |         | R <sup>2</sup>               | Adj. R <sup>2</sup> | Coeff. (SE)                   | t-test (Sig.) |
| 21-30 weeks          | Model 1 | 0.02923                      | 0.01932             | 146.36 <sup>a1</sup> (11.044) | 13.25 (0.000) |
|                      |         |                              |                     | 7.072 <sup>b1</sup> (4.117)   | 1.718 (0.089) |
|                      | Model 2 | 0.521                        | 0.526               | 74.032 <sup>a2</sup> (8.83)   | 8.38 (0.000)  |
|                      |         |                              |                     | 15.827 <sup>b2</sup> (1.53)   | 10.32 (0.000) |
| 31-40 weeks          | Model 3 | 0.452                        | 0.456               | 84.53 <sup>a3</sup> (17.80)   | 4.75 (0.000)  |
|                      |         |                              |                     | 48.76 <sup>b3</sup> (5.34)    | 9.130 (0.000) |
|                      | Model 4 | 0.763                        | 0.761               | 62.51 <sup>a4</sup> (10.37)   | 6.03 (0.000)  |
|                      |         |                              |                     | 21.48 <sup>b4</sup> (1.20)    | 17.78(0.000)  |

*a* – Coeff. constant of the model; *b* – Coeff. Constant of independent variable (Placenta thickness and BPD, respectively) applied in the Model; *y* – dependent variable (Gestational age); Model 1&3 – GS versus PL; Model 2&4 – GS versus BPD

Table 3 indicates the regression model summary between GS versus PL and BPD for (20-30 & 30-40 weeks). Linear regression lines of Gestational age (GS) on BPD, as well as Placenta thickness (PL), have been derived for 21-30 and 31-40 weeks of gestational period. It was found a very good association was found between GS and BPD, as well as PL, where 76 % & 45% variations in GS are explained by BPD & PL, respectively, with the corresponding models 4 & 5. Gestational age can be estimated using models 1-4. Parameters of models (1-4) were found statistically significant, except parameter b1. Its residual graphs are shown in Figures 4 & 5 for 21-30 and 31-40 weeks, respectively. It was observed from the QQ and fitted-residual plots that residuals were found almost normally distributed except few variations. Models (1-4) were explained well in estimating GS, BPD, and PL for 21-30 and 31-40 weeks.



**Figure 4.** Graphs of residual (fitted, QQ, etc.) for model 1&2.

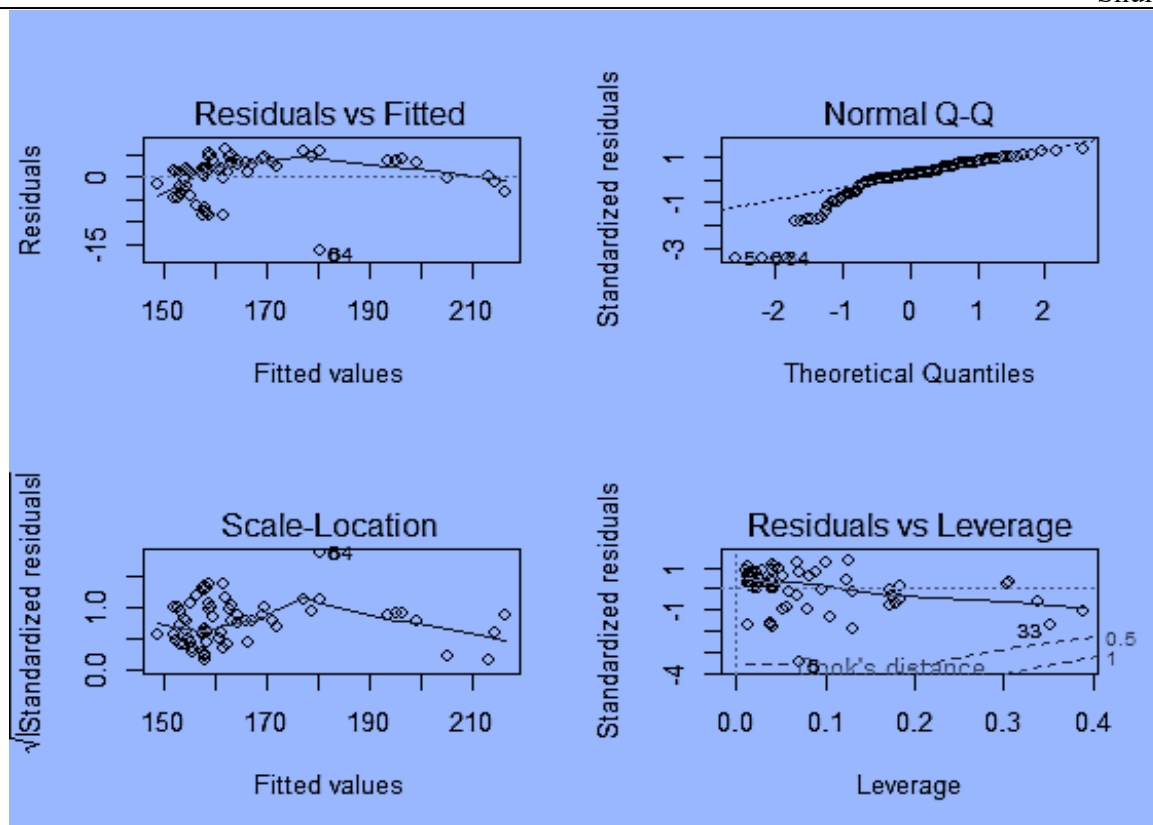


**Figure 5.** Graphs of residual (fitted, QQ, etc.) for model 3&4.

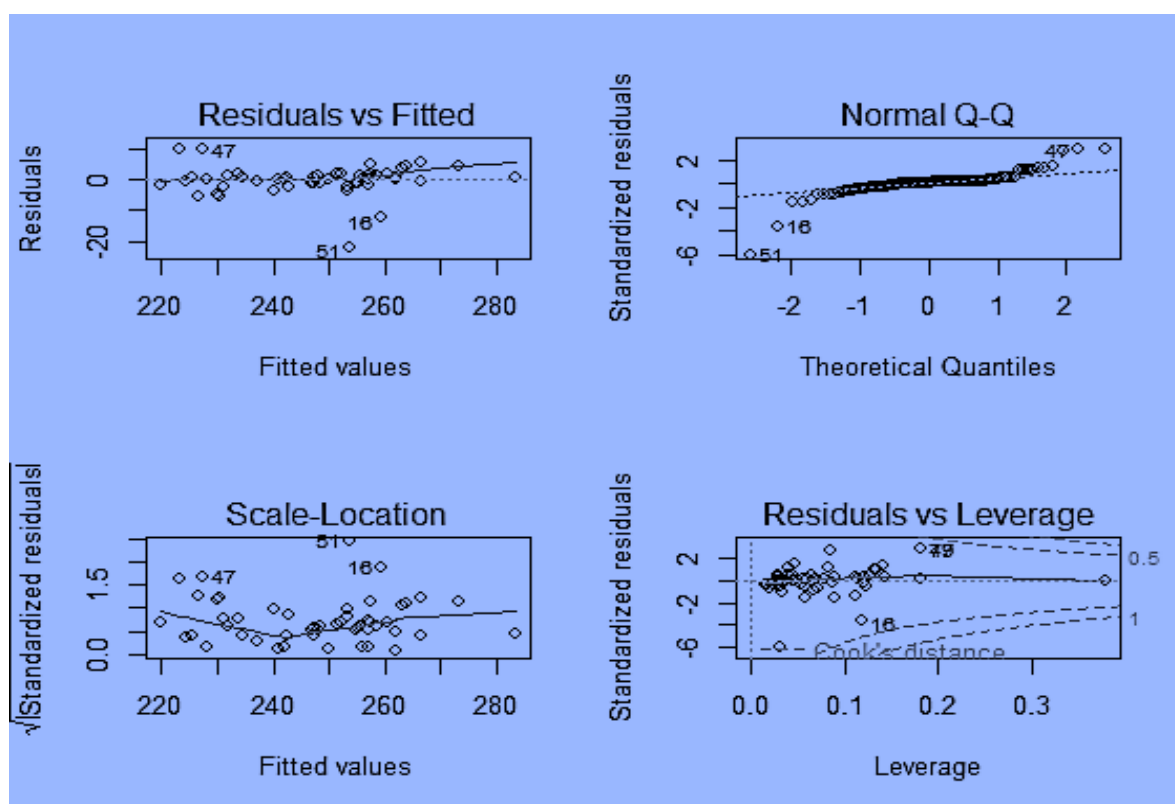
**Table 4.** Model summary among GS and Fetal parameters for both (second & third trimester age)

| Gestational Age | Model-5&6<br>(R <sup>2</sup> & Adjusted R <sup>2</sup> )                         | Model  | Unstandardized Coefficients |            | t      | Sig.  |
|-----------------|----------------------------------------------------------------------------------|--------|-----------------------------|------------|--------|-------|
|                 |                                                                                  |        | Coeff.                      | Std. Error |        |       |
| 21-30 weeks     | <b>Model-5</b><br>0.908 (R <sup>2</sup> )<br>And<br>0.902 (Adj. R <sup>2</sup> ) | Const. | 124.966                     | 5.848      | 21.369 | .000  |
|                 |                                                                                  | BPD    | 1.494                       | 1.308      | 1.142  | .256  |
|                 |                                                                                  | HC     | -.344                       | .943       | -.365  | .716  |
|                 |                                                                                  | AC     | .539                        | .904       | .596   | .553  |
|                 |                                                                                  | FL     | -.615                       | 1.696      | -.363  | .718  |
|                 |                                                                                  | PL     | -1.212                      | 1.598      | -.758  | .450  |
|                 |                                                                                  | Weight | .053                        | .003       | 18.328 | .000  |
| 31-40 weeks     | <b>Model-6</b><br>0.913 (R <sup>2</sup> )<br>And<br>0.908 (Adj. R <sup>2</sup> ) | Const. | 71.44                       | 25.02      | 2.85   | 0.005 |
|                 |                                                                                  | BPD    | 9.28                        | 3.34       | 2.77   | 0.006 |
|                 |                                                                                  | HC     | -0.572                      | 0.904      | -0.633 | 0.528 |
|                 |                                                                                  | AC     | 3.28                        | 0.808      | 4.06   | 0.000 |
|                 |                                                                                  | FL     | -0.498                      | 2.390      | -0.289 | 0.835 |
|                 |                                                                                  | PL     | 0.118                       | 3.132      | 0.038  | 0.969 |
|                 |                                                                                  | Weight | 0.005                       | 0.004      | 1.360  | 0.177 |

Table 4 shows the regression model summary between GS versus fetal parameters (BPD, HC, AC, FL, PL, and weight) for (21-30 & 31-40 weeks). The linear regression line of Gestational age (GS) is considered as a dependent variable, and fetal parameters are considered as independent variables, which have been derived for the second and third trimester period in equations 5 & 6, respectively. There was found very strong association was found between GS and fetal parameters, where 90 % & 91% variations in GS are explained by fetal parameters with models 5 & 6, respectively. Gestational age can be estimated using equations 5 & 6. Parameters of models (5&6) were found statistically significant, except few. Its residual plots are shown in Figures 6&7 for 21-30 and 31-40 weeks, respectively. It was observed from the QQ and fitted-residuals plot that residuals were found to be almost normally distributed. Models (5&6) explained well about GS using fetal parameters for 21-30 and 31-40 weeks. It was observed that Gestational age can be estimated accurately using combined linear regression with fetal parameters in comparison to using only Placenta thickness.



**Figure 6.** Graphs of residual (fitted, QQ, residual, scale, leverage.) for model-5 (GS 21-30 weeks).



**Figure 7.** Graphs of residual (fitted, QQ, residual, scale, leverage.) for model-6 (31-40 weeks).

## 4. Discussions

This section discusses and compares results with those of previous studies. Linear regression models and descriptive statistics of fetal parameters using tables and graphs have been applied in the study for two gestational ages, 21-30 and 31 to 40 weeks.

Mean scores for BPD, placenta thickness, and weight of fetal were found to be  $5.75 \pm 0.711$  cm;  $2.56 \pm 0.37$  cm;  $654.31 \pm 266.23$  gm, and  $8.57 \pm 0.50$  cm;  $3.33 \pm 0.17$  cm;  $2582.56 \pm 453.35$  gm for the period of 21-30 and 31-40 weeks, respectively. It was almost like the value of placenta thickness mentioned by Mital *et al.* (2002) (37.5mm) at 39 gestations who conducted similar work in Rajasthan, India. However, Ohagwu *et al.* (2008) reported a mean of Placenta thickness  $4.50 \pm 0.63$  cm at 39 weeks of gestation in a similar population among Benue people of Nigeria. It was higher than this study it may be due to race and place of destination. In a similar context, a study was conducted in the same region (Nigeria) and was found  $4.2 \pm 0.29$  cm, (Agwuna *et al.*, 2016).

A similar study was conducted by Karthikeyan *et al.* (2012) who reported that the placental thickness increases by more than 2mm in a week in the first trimester. From the 15th to the 20th week, the placental thickness increased by more than 4 mm and from the 20th to the 25th week, it increased by more than 5mm. It was observed in this study that from 21-30 to 31-40 weeks, the BPD and placenta thickness of selected respondents were increased by 2.61 cm and 0.60cm whereas the weight of the fetus was increased by 2115.37 gm. In the first 21-30 gestational age, Placenta thickness is increased by 2.70 mm (approx.) per week in our study, whereas in the 31-40 weeks, it is increased by 3.45mm (approx.) per week.

Models 1-4 can be used as a reference point for estimating gestational age (GS) using BPD and PL (Placenta thickness) in both 21-30 and 31-40 weeks. There was a significant positive relationship between gestation age (GS) and Placenta thickness (PL) was observed. This implies that the PT, GS, and BPD are linearly related.

The following linear equations show the relationship between GA (Y) in days and PT & BPD in cm. In the 21-30 weeks,  $GS_{21-30weeks} = 146.36 + 7.07PL_{21-30weeks}$  and  $GS_{21-30weeks} = 74.03 + 15.8BPD_{21-30weeks}$ . In the 31-40 weeks,  $GS_{31-40weeks} = 84.53 + 48.76PL_{31-40weeks}$  and  $GS_{31-40weeks} = 62.51 + 21.48BPD_{31-40weeks}$ .

The relationship between GS and fetal parameters (BPD, AC, FL, etc.) are obtained as follows:  $GS_{21-30weeks} = 124.96 + 1.49BPD - 0.34HC + 0.54AC - 0.61FL - 1.2PL + 0.05Weight$  and  $GS_{31-40weeks} = 71.44 + 9.28BPD - 0.57HC + 3.28AC - 0.49FL + 0.12PL + 0.005Weight$  for 21-30 and 31-40 weeks respectively. With these equations, GS can be estimated in days by substituting the measured value of fetal parameters (BPD, HC, AC, FL, PL, and Weight) in these equations.

For example, GS (21-30) can be calculated, where values of BPD=5.5cm, HC=20.5cm, AC=17.6cm, FL=3.9cm, PL=2.6cm, Weight=516 randomly selected from the data. The value of GS for 21-30 weeks using equation (5) was found to be 158 days, whereas using equations (1) & (2) was found to be 164 days and 161 days, respectively. However, the actual value of GS is observed to be 159 days, which is much closer (158 days) to the calculated GS by model (5). In this way, it was observed that model (5) gives a better estimate for GS in comparison to models (1) & (2).

Similarly, it can also be calculated for 31-40 weeks. For example, values corresponding to fetal parameters (BPD=8.1cm, HC=31.3 cm, AC=31.9cm, FL=6.1 cm, PL=3.34cm, and weight=2428 gm) are taken from the data. It was found that the calculated value of GS (241 days) is much closer to the observed value (243). Corresponding values of GS using models 3 & 4 were calculated 247 days and

238 days respectively, which are over and estimate the results obtained by models 3 & 4. It can be concluded that models 5 & 6 are advisable in place of models 1 & 2 and models 3 & 4 for estimating gestational age (GS) for pregnant women.

In this study, from Tables 3 & 4 and Figures 2 to 6, it is obvious that Placenta thickness is in a linear relationship with GS, and it was also observed that there is a linear relationship between PL and fetal parameters. This study was related to numerous other studies (Ohagwu, 2009a; Ohagwu, 2009b; Anupama, 2001). So, the substitution of any abnormal fetal parameters like BPD in hydrocephalus with PT in USG, in the GS estimation, can be expressed. Since previous studies (Ohagwu, 2009a; Ohagwu, 2009b; Anupama, 2001) were reported as cross-sectional studies, based on the above studies, it may not be advisable that PL can be used as a reliable predictor of gestational age. As we expressed in the above example, GS can be estimated accurately using all fetal parameters, which is consistent with the result reported by Karthikeyan *et al.* (2012).

## 5. Concluding Remarks

In the study, six linear regression models were applied to estimate the gestational age (GS) of pregnant women. The accuracy of models has been checked using residual plots. It was observed that there is a significant association between GS and BPD as well as PL for both periods (21-30 & 31-40 weeks), however very good relation was observed between GS and BPD in comparison to the relationship between GS and PL. It has been compared among the models for both periods (21-30 & 31-40 weeks) for estimation of gestational age in days. It was found that models 5 & 6 were better in comparison to models 1 to 4. We conclude that fetal parameters (independent variable) can be used as a predictor of the GS. It was observed that Gestational age can be estimated accurately using a combined linear regression with fetal parameters in comparison to using only Placenta thickness.

## 6. Limitations

The authors do not have any research funds to collect a larger sample size.

After agreeing with written consent, 100 pregnant women (20-40 weeks) were selected. Some of the respondents did not agree to respond due to either fear or some complications. Time constraints were also a factor.

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## Author's contribution

Conceptualization: SHUKLA, K. K.; Data curation: KUMAR, A.; Formal analysis: SHUKLA, K. K.; Funding acquisition: NIL; Investigation: KUMAR, A.; Methodology: SHUKLA, K. K.; Project administration: NA Software: SHUKLA, K. K.; Resources: JEE, K.; Supervision: SHUKLA, K. K.; Validation: SHUKLA, K. K.; Visualization: SHUKLA, K. K.; Writing - original draft: JEE, K.; Writing - review and editing: SHUKLA, K. K.

## Conflicts of Interest:

There is no conflict of interest.

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