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# Fetal ultrasound parameters: Reference values for a local perspective

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## Abstract

**Background:** Fetal biometry, with the help of ultrasonography (USG) provides the most reliable and important information about fetal growth and well-being. Frequently used parameters for fetal measurements by this method are the biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL). These fetal dimensions depend upon the racial demographic characteristics, nutrition, genetics and many more environmental factors of a particular population. **Aims:** The purpose of the present investigation was to define and analyze these fetal biometric parameters in our local population and to compare them with the given norms. **Methods:** This cross-sectional study with convenience sampling was conducted on a total of 425 fetuses with a period of gestation between 18 to 38 weeks. Descriptive statistics was used to calculate the mean with standard deviation and 95% confidence interval (CI) for each fetal parameter in each gestational week. **Results:** Mean of BPD and FL in our population are similar to the mean values given by Hadlock throughout the pregnancy, except near the end of the third trimester where our population shows a slightly lower range of mean values. HC and AC fall below the lower range of Hadlock as early as 24 weeks of pregnancy. **Conclusions:** Fetal biometric parameters in the studied population are at the lower range of established nomograms by Hadlock on white fetuses, more so with the progression of pregnancy.

**Key words:** Fetal-biometry; gestational age; Hadlock standard reference charts; ultrasound

## Introduction

Tremendous progress in the application of ultrasonography (USG) as a diagnostic modality has revolutionized the management towards better care due to its non-invasive and non-ionizing nature besides the cost-effectiveness leading to its wider acceptability. Fetal biometry, with the help of USG provides the most reliable and important information about fetal growth and well-being. This methodology is devoted to the measurement of the several parts of fetal anatomy and the growth of these fetal parts throughout pregnancy. Fetal growth is defined as the time-dependent changes in body dimensions of the fetus that occur during the pregnancy. The sonographic measurements of the fetus are beneficial in providing information about fetal growth in comparison to set standards of fetal biometry as per the gestational age.[1] These standard charts are used by most of the USG machines to assign gestational age (GA), expected date of delivery (EDOD), estimated fetal birth weight (EFBW) and in diagnosing growth disturbances in the fetus.

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Accurate knowledge of gestational age is the key to successful antepartum care and for successful planning of appropriate intervention or treatment.[2] Multiple standard fetal biometric charts are available for prediction of Gestational Age (GA) from the given fetal parameters which include measurement of gestational sac, crown rump length (CRL), fetal biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC), and femur length (FL). The most frequently used parameters in the second and third trimester of pregnancy are the BPD, HC, AC and FL. These parameters are considered as the 'gold standard' as they collectively assess the GA to the highest degree of accuracy.

Reference ranges for these four parameters of fetal biometry by ultrasound were initially reported by Hadlock[3-6] on the populations of developed countries. Since then many workers have worked on different population groups and established reference charts pertaining their own populations because of the difference from the established nomograms, but the USG machines in our country are still using the Hadlock standard fetal growth charts and tables as reference for estimation of the gestational age of the fetus.

Since the fetal dimensions have been known to depend upon the racial characteristics, genetics, nutrition and many more environmental factors of a particular population, thus the biometric curves obtained from one population may not accurately estimate the fetal gestational age when used for another population. This study has been undertaken to define and analyze the mean of the four fetal biometric parameters (BPD, FL HC, and AC) for gestational weeks from 18 to 38 weeks, for the local population of this region of Southern Punjab, India.

## Methods

This study was conducted for a period of six months from October 2015 to March 2016 on pregnant females attending the Department of Gynaecology and Obstetrics of Adesh Institute of Medical Sciences and Research, Bathinda for routine antenatal assessment. Fetuses of females who were declared as normal, with a viable singleton pregnancy by the obstetrician and were referred to the Ultrasonographic section of the Department of Radiodiagnosis and Imaging of this Institute for assessment of antenatal fetal wellbeing using fetal biometry were scrutinized.

Only healthy females with regular menstrual cycles, having no maternal disorder that could affect the normal growth of the fetus and with a known date of last menstrual period (LMP) were included. This cross-sectional study with convenience sampling was conducted on the fetuses from 18 to 38 weeks of gestation (calculated from the known LMP) of these females. Every fetus was included in the study only once during their gestation period.

The females were taken for ultrasonography after they completely filled the form-F, duly signed by the radiologist conducting sonography and the women undergoing sonography. These Obstetrical ultrasounds were carried out using 3.5 MHz convex transducer on GE, E-8 ultrasound machine. Measurements of BPD, HC, AC, and FL of all the fetuses were taken by a single radiologist using the standard methods. In case any abnormality was detected in the fetus on USG, the fetus was not included in the study.

Quantitative data of the fetal parameters were entered in the Microsoft Excel version 2010. The analysis was carried out using Statistical package for social sciences (SPSS) for Windows version 17.0, Released 2008 (SPSS Inc., Chicago, IL). The data was evaluated using the Kolmogorov–Smirnov normality test and was found to have non-normal distribution. Descriptive statistics was used to calculate the mean with standard deviation and 95% confidence interval (CI) for each fetal parameter in each gestational week. The percentage of the difference of mean was calculated for the mean values in the present study and from the mean of Hadlock's standard reference values. Negative values in percentage of mean indicate that fetal biometry values in our study are smaller than Hadlock's values for that gestational age. Graphs were used to enhance the clarity of growth trends of various fetal parameters against the gestational age by LMP and to compare means of the present study to the reference values given by Hadlock (3-6).

Informed consent for inclusion in the study was taken from the selected females. Data were anonymized prior to analysis. The present study was approved by the Institutional Research and Ethics Committees of Adesh University.

## Results

The study was conducted on 425 pregnant females with 217 (51%) in the second trimester (18-28 weeks) and 208 (49%) in the third trimester (29- 38 weeks) of pregnancy. The age group of the females included in the study was from 18 to 39 years and the gravida ranged from 1 to 6. There were only 7 cases of gravida 5 and 4 cases of gravida 6, rest all were from gravida 1 to 4. The parity of these females ranged from 1 to 5 with only 3 cases of para 4 and only one case of para 5.

The mean of all the fetal biometric parameters (BPD, HC, AC, and FL in millimeters) with the standard deviation (SD) against the weeks of gestation (as per LMP) along with 95% confidence interval (CI) have been presented in Tables 1 and 2. The number of cases studied for each week of gestation has been represented by 'n' in these tables.

**Table 1: Mean of fetal parameters (in mm) with standard deviation as observed from the present study for various gestational weeks of the second trimester by last menstrual period**

| GA in wks | *n* | BPD (in mm) | | FL (in mm) | | HC (in mm) | | AC (in mm) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean±SD | 95% CI | Mean±SD | 95% CI | Mean±SD | 95% CI | Mean±SD | 95% CI |
| 18 | 35 | 42.5±4.6 | 40.9-44.1 | 27. ± 04.1 | 27.2-30.0 | 153.2±17.7 | 152.0-164.2 | 129.8±24.2 | 121.4-138.0 |
| 19 | 18 | 45.6±07.7 | 41.7-49.4 | 30.6±05.4 | 27.8-33.2 | 166.9±23.9 | 155.0-178.8 | 138.2±24.3 | 126.0-150.2 |
| 20 | 18 | 47.7±03.1 | 46.1-49.2 | 32.6±02.5 | 31.3-33.8 | 175.7±13.0 | 169.1-182.1 | 147.9±10.7 | 142.5-153'2 |
| 21 | 14 | 50.9±03.1 | 49.0-52.7 | 37.4±04.5 | 34.7-40.0 | 189.1±11.1 | 182.6-195.5 | 159.0±28.9 | 142.3-185.8 |
| 22 | 29 | 52.7±07.5 | 49.8-55.5 | 38.2±06.9 | 35.5-40.7 | 191.7±36.8 | 177.7-205.6 | 168.7±29.8 | 157.3-180.0 |
| 23 | 17 | 57.7±08.8 | 53.1-62.2 | 42.0±09.1 | 37.3-46.6 | 211.7±30.4 | 196.0-227.3 | 180.0±25.9 | 168.5-198.2 |
| 24 | 10 | 58.9±06.9 | 50.6-61.2 | 43.6±07.9 | 32.5-44.7 | 218.7±26.5 | 190.3-231.0 | 183.4±28.9 | 160.1-199.9 |
| 25 | 18 | 61.3±08.1 | 57.2-65.2 | 45.6±06.1 | 42.5-48.6 | 226.1±30.2 | 211.0-241.1 | 199.1±24.6 | 186.8-211.3 |
| 26 | 20 | 62.4±06.3 | 59.4-65.3 | 48.8±05.4 | 43.2-48.3 | 230.5±22.7 | 219.9-241.1 | 209.1±20.0 | 179.7-218.4 |
| 27 | 10 | 66.9±05.3 | 63.1-70.7 | 51.0±03.0 | 48.8-53.1 | 247.4±14.0 | 237.4-257.4 | 220.8±12.5 | 211.8-229.7 |
| 28 | 28 | 70.1±05.0 | 68.1-72.0 | 52.2±03.9 | 50.6-53.6 | 255.7±18.9 | 248.3-262.9 | 225.7±17.6 | 218.9-232.5 |

BPD: Biparietal diameter; HC: Head circumference; AC: Abdominal circumference; FL: Femur length; GA: Gestational age; SD: Standard deviation

**Table 2: Mean of fetal parameters (in mm) with standard deviation as observed from the present study for various gestational weeks of the third trimester by last menstrual period**

| GA in wks | *n* | BPD (in mm) | | FL (in mm) | | HC (in mm) | | AC (in mm) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean±SD | 95% CI | Mean±SD | 95% CI | Mean±SD | 95% CI | Mean±SD | 95% CI |
| 29 | 24 | 75.1±05.2 | 72.8-77.2 | 56.4±03.9 | 54.7-58.0 | 273.2±16.5 | 266.2-280.2 | 250.6±18.8 | 242.6-258.5 |
| 30 | 12 | 77.0±05.1 | 73.7-80.2 | 57.4±04.5 | 54.5-60.2 | 276.0±16.5 | 265.5-286.4 | 253.1±24.6 | 237.5-268.7 |
| 31 | 15 | 78.5±05.4 | 75.5-81.4 | 59.1±04.2 | 56.7-61.3 | 281.6±25.6 | 277.6-295.0 | 259.8±23.5 | 246.7-272.8 |
| 32 | 19 | 79.0±07.6 | 73.3-80.6 | 59.8±06.9 | 56.5-63.1 | 286.3±15.6 | 269.2-293.9 | 261.4±25.7 | 249.0-273.8 |
| 33 | 13 | 79.4±05.4 | 74.9-83.9 | 61.2±04.8 | 58.8-67.0 | 288.6±24.8 | 277.9-299.3 | 272.0±18.2 | 247.9-289.3 |
| 34 | 16 | 82.7±06.9 | 79.0-86.4 | 63.3±05.5 | 60.3-66.2 | 297.9±2.22 | 286.0-309.6 | 281.7±29.4 | 266.0-297.3 |
| 35 | 44 | 84.8±03.9 | 83.5-85.9 | 66.7±03.5 | 65.5-67.7 | 304.8±39.0 | 292.9-316.6 | 294.8±16.1 | 289.8-299.6 |
| 36 | 28 | 86.8±04.6 | 84.9-88.5 | 68.0±03.7 | 66.5-69.4 | 313.2±13.6 | 307.9-318.4 | 304.8±19.7 | 297.1-312.4 |
| 37 | 14 | 88.7±03.9 | 86.6-90.6 | 69.5±02.5 | 68.1-70.7 | 315.7±13.6 | 308.6-322.6 | 315.0±12.1 | 308.8-321.2 |
| 38 | 12 | 91.2±03.8 | 88.2-94.1 | 72.1±02.9 | 69.8-74.3 | 331.6±11.6 | 322.6-340.4 | 321.5±16.5 | 308.8-334.1 |

BPD: Biparietal diameter; HC: Head circumference; AC: Abdominal circumference; FL: Femur length; GA: Gestational age; SD: Standard deviation

Tables 3-6 compares the mean of the four different fetal biometric parameters of present study with standard reference values by Hadlock[3-6] along with the percentage difference of the mean between the values derived from the present investigation to those of Hadlock's mean in standard reference charts for the given gestational age.

The values of the 425 cases for each parameter (BPD, HC, AC, and FL) were plotted against the gestational age by LMP [Figure 1] along with the error bars for 2 SD and a polynomial regression trend line which calculated the $R^2$ for BPD, HC, AC, and FL as 0.861, 0.823, 0.858, and 0.453, respectively.

**Table 3: Comparison of mean of fetal BPD and FL (in mm) of present study with Hadlock's standard reference values for the second trimester along with percentage difference of mean between them**

| GA in wks by LMP | *n* | BPD | | | FL | | |
|---|---|---|---|---|---|---|---|
| | | Present study (mean) | Hadlock[3] | % Difference of mean | Present study (mean) | Hadlock[6] | % Difference of mean |
| 18 | 35 | 42.5 | 39 | 8.24 | 28.7 | 27 | 5.92 |
| 19 | 18 | 45.6 | 43 | 5.70 | 30.6 | 30 | 1.96 |
| 20 | 18 | 47.7 | 46 | 3.56 | 32.6 | 33 | -1.23 |
| 21 | 14 | 50.91 | 50 | 1.79 | 37.41 | 35 | 6.44 |
| 22 | 29 | 52.7 | 53 | -0.57 | 38.2 | 38 | 0.52 |
| 23 | 17 | 57.7 | 56 | 2.95 | 42 | 41 | 2.38 |
| 24 | 10 | 58.9 | 59 | -0.01 | 43.6 | 44 | -0.91 |
| 25 | 18 | 61.3 | 62 | -1.14 | 45.6 | 46 | -0.88 |
| 26 | 20 | 62.4 | 65 | -4.17 | 48.8 | 49 | -0.40 |
| 27 | 10 | 66.9 | 68 | -1.64 | 51 | 51 | 0.00 |
| 28 | 28 | 70.1 | 71 | -1.28 | 52.2 | 54 | -3.45 |

BPD: Biparietal diameter; FL: Femur length; GA: Gestational age; LMP: Last menstrual period

**Table 4: Comparison of mean of BPD and FL (in mm) of present study with Hadlock's standard reference values of the third trimester along with percentage difference of mean between them**

| GA in wks by LMP | *n* | BPD | | | FL | | |
|---|---|---|---|---|---|---|---|
| | | Present study (mean) | Hadlock[3] | % Difference of mean | Present study (mean) | Hadlock[6] | % Difference of mean |
| 29 | 24 | 75.1 | 73 | 2.80 | 56.4 | 56 | 0.71 |
| 30 | 12 | 77 | 76 | 1.30 | 57.4 | 58 | -1.05 |
| 31 | 15 | 78.5 | 78 | 0.64 | 59.1 | 60 | -1.52 |
| 32 | 19 | 79 | 81 | -2.53 | 59.8 | 62 | -3.68 |
| 33 | 13 | 79.4 | 83 | -4.53 | 61.2 | 64 | -4.58 |
| 34 | 16 | 82.7 | 85 | -2.78 | 63.3 | 66 | -4.27 |
| 35 | 44 | 84.8 | 87 | -2.59 | 66.7 | 68 | -1.95 |
| 36 | 28 | 86.8 | 89 | -2.53 | 68 | 70 | -2.94 |
| 37 | 14 | 88.7 | 90 | -1.47 | 69.5 | 72 | -3.60 |
| 38 | 12 | 89.2 | 92 | -3.14 | 70.1 | 74 | -5.56 |
| 39 | 7 | 89.6 | 93 | -3.79 | 70.8 | 75 | -5.93 |
| 40 | 5 | 89.5 | 94 | -5.02 | 71.1 | 77 | -8.2 |

BPD: Biparietal diameter; FL: Femur length; GA: Gestational age; LMP: Last menstrual period

**Table 5: Comparison of mean of HC and AC (in mm) of present study with Hadlock's standard reference values of second trimester along with percentage difference of mean between them**

| GA in wks by LMP | *n* | HC | | | AC | | |
|---|---|---|---|---|---|---|---|
| | | Present study (mean) | Hadlock[4] | % Difference of mean | Present study (mean) | Hadlock[5] | % Difference of mean |
| 18 | 35 | 153.2 | 151 | 4.55 | 129.8 | 125 | 3.70 |
| 19 | 18 | 166.9 | 164 | 1.74 | 138.2 | 137 | 0.87 |
| 20 | 18 | 175.7 | 177 | -0.74 | 147.9 | 150 | -1.42 |
| 21 | 14 | 189.1 | 189 | 0.05 | 159 | 162 | -1.89 |
| 22 | 29 | 191.7 | 201 | -4.85 | 168.7 | 174 | -3.14 |
| 23 | 17 | 211.7 | 213 | -0.61 | 180 | 185 | -2.77 |
| 24 | 10 | 218.7 | 224 | -2.42 | 183.4 | 197 | -7.41 |
| 25 | 18 | 226.1 | 235 | -3.94 | 199.1 | 208 | -4.47 |
| 26 | 20 | 230.5 | 246 | -6.72 | 209.1 | 219 | -4.73 |
| 27 | 10 | 247.4 | 256 | -3.48 | 220.8 | 230 | -4.17 |
| 28 | 28 | 255.7 | 266 | -4.03 | 225.7 | 240 | -6.34 |

BPD: Biparietal diameter; HC: Head circumference; AC: Abdominal circumference; GA: Gestational age; LMP: Last menstrual period

Figure 2 is the graphical representation of a comparison of means of present study with those of mean reference values given by Hadlock depicts that BPD in the present study has almost similar mean values for GA as that of Hadlock except

**Table 6: Comparison of mean of HC and AC (in mm) of present study with Hadlock's standard reference values of third trimester along with percentage difference of mean between them**

| GA in wks by LMP | *n* | HC | | | AC | | |
|---|---|---|---|---|---|---|---|
| | | Present study (mean) | Hadlock[4] | % Difference of mean | Present study (mean) | Hadlock[5] | % Difference of mean |
| 29 | 24 | 273.2 | 275 | -0.66 | 250.6 | 251 | -0.16 |
| 30 | 12 | 276 | 284 | -2.90 | 253.1 | 261 | -3.12 |
| 31 | 15 | 281.6 | 293 | -2.34 | 259.8 | 271 | -4.31 |
| 32 | 19 | 286.3 | 301 | -6.89 | 261.4 | 281 | -7.50 |
| 33 | 13 | 288.6 | 304 | -5.34 | 272 | 291 | -6.96 |
| 34 | 16 | 297.9 | 308 | -3.39 | 281.7 | 300 | -6.50 |
| 35 | 44 | 304.8 | 315 | -3.35 | 294.8 | 309 | -4.82 |
| 36 | 28 | 313.2 | 328 | -4.73 | 304.8 | 318 | -4.33 |
| 37 | 14 | 315.7 | 333 | -5.48 | 315 | 327 | -3.81 |
| 38 | 12 | 331.6 | 338 | -1.93 | 321.5 | 336 | -4.51 |
| 39 | 7 | 334.5 | 342 | -2.24 | 328.5 | 344 | -4.72 |
| 40 | 5 | 336.7 | 346 | -2.76 | 334.2 | 353 | -5.62 |

BPD: Biparietal diameter; FL: Femur length; GA: Gestational age; LMP: Last menstrual period

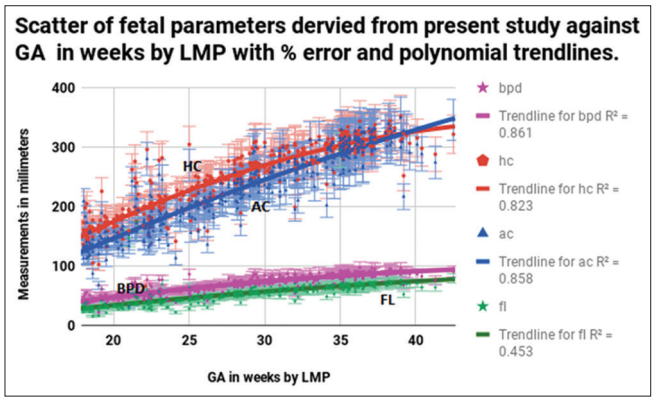


**Figure 1:** Scatter of fetal parameters from this study

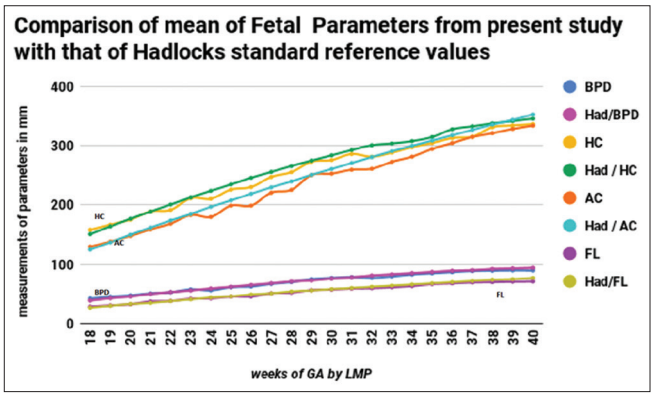


**Figure 2:** Comparative trend of reference values of this study with the standard Hadlock's reference values

at the end of the third trimester where the reported population in the present research shows slightly smaller BPD than the standard values. This plot also clarifies that the mean values for FL in the present investigation are very similar to that by Hadlock. Also, the mean for HC and AC has followed the trend as that of Hadlock till 24 weeks but has fallen to values lower than the mean given by Hadlock in the third trimester with a markedly obvious difference. A closer look shows that though the values are smaller, the trend of growth for all parameters is the same as that of Hadlock. It is also noted that BPD and FL follow a regular trend of growth but their rate of growth is less than the rate of growth of HC and AC.

## Discussion

Tables 3-6 show that the percentage difference of the mean for BPD varies from -5.02 to 8.24, for FL it is from -8.28 to 6.44, for HC it ranges from -6.89 to 4.55 and for AC the range of this difference of mean is -7.50 to 3.70. It is obvious that the percentage difference of mean is more negative as the pregnancy advances showing that values of our means are smaller than the standard reference mean values of Hadlock in the later part of the pregnancy. This finding is similar to the finding reported by Babuta *et al*.[2] in their study on Indian fetuses from a different geographical region.

Comparison of fetal biometric parameters from various studies[7-12] reported by authors on different population groups in India and other countries, has revealed that none of the fetal parameters from any of the population groups exactly coincide with the reference charts by Hadlock or with any other standard reference charts. Studies conducted on white fetuses[8-9] have mostly shown a higher range of mean values than Indian and Asian groups.

In a study on 1539 infants of different races as white, Asian Indian, Chinese, Hispanic and others at Northern California, it was found that Asian and Hispanic babies had shorter mean lengths with smaller mean HC than white babies.[13] Kinare *et al*.[14] described fetal size on sonography in the rural Indian population and compared it with those in European and urban Indian populations. He reported that the fetal FL was comparable whereas HC was variable in early pregnancy and that beyond 28 weeks, all measurements for Indian fetuses were smaller than the

European references. Findings from the above studies are similar to that of the present study as our mean values for fetal biometry are smaller than the means of white fetuses studied by Hadlock (3-6).

Many other researchers[15-18] supported that in Asians, FL and BPD in early pregnancy are nearly similar to the standard charts and that AC and HC are below the lower range as per the standard charts. In the third trimester, the mean difference for all fetal parameters increases gradually from the standard values. A similar pattern has also been observed in the present study for all the fetal parameters.

Ruvolo *et al*.[18] who evaluated a racially mixed population of Blacks, Asians, and Caucasians stated that there is no significant difference in FL between the populations he studied, though BPD, HC, and AC are significantly different. Yeo *et al*.[16] said that the Chinese and Malai fetal FL appeared similar but was shorter than the Indian FL though the mean values of HC, AC of Chinese and Indian fetuses in Singapore were the same. Similarly, Lachman and Shen,[17] conducted a study on 128 cases of Chinese fetuses and found a statistically significant difference in fetal FL between the Chinese population and established different FL nomograms. In the present study FL is very close to the values in standard charts by Hadlock,[19] therefore the FL in Indian fetus has been found to be in the standard range[20] and thus our findings support the finding by Ruvolo *et al*.[18] that FL in Indian fetus in not much variable than standard. So, the regression equations developed by Hadlock *et al*.[21] for fetal parameters, from white middle-class population appear to be applicable to the populations of our socioeconomic and racial characteristics, when compared for FL and BPD, but not for HC and AC.

Since the anatomic dimensions of fetus vary according to the socioeconomic factors, nutritional status, build, environmental factors, ethnic groups and the genetic background, it may be because of these variations that the Indian fetus usually falls in the lower ranges of growth curves proposed for the western population.[22] Till date, in India, we do not have our own population-specific tables for the determination of gestational age and use of Western normograms may lead to misdiagnosing fetal growth for gestational age in the Indian population.[17]

The use of sonography is the method of choice to assess fetal size and growth[23,24] and this knowledge of growth and well being of the fetus has an important role in modern prenatal care. It therefore, emphasizes the fact that the standard charts may need to be adjusted as per the local population, for clinical use, to increase diagnostic and predictive performance[25] of fetal sonography.

In the present study, the measurements were made according to standardized protocols by a single experienced medical sonologist, ensuring high-quality measurements and minimizing interobserver variation, but limitation of the study is that, the data was collected by convenient sampling and proper sample size estimation was not done for the study population. There are several studies on fetal biometry for different ethnic groups living in India, but there is no standard chart for the Indian population, especially the Punjabi population. Further studies on the same population are recommended with details on the ethnicity and nutritional status of the females to be able to construct our own reference values for fetal biometry for local prospective as it would help in improving prenatal care in this region of India.

### Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

### Conflicts of interest

There are no conflicts of interest.

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