Patterns of Fetal Growth in a Rural Indian Cohort and Comparison With a Western European Population

Data From the Pune Maternal Nutrition Study

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Objective. The purpose of this study was to describe fetal size on sonography in a rural Indian population and compare it with those in European and urban Indian populations. ***Methods***. Participants were from the Pune Maternal Nutrition Study of India. Fetal growth curves were constructed from serial ultrasound scans at approximately 18, 30, and 36 weeks' gestation in 653 singleton pregnancies. Measurements included femur length (FL), abdominal circumference (AC), biparietal diameter (BPD), and occipitofrontal diameter, from which head circumference (HC) was estimated. Measurements were compared with data from a large population-based study in France and a study of urban mothers in Vellore, south India. ***Results.*** Fetal AC and BPD were smaller than the French reference at 18 weeks' gestation (–1.38 and –1.30 SD, respectively), whereas FL and HC were more comparable (–0.77 and –0.59 SD). The deficit remained similar at 36 weeks for AC (–0.97 SD), FL (–0.43 SD), and HC (–0.52 SD) and increased for BPD (–2.3 SD). Sonography at 18 weeks underestimated gestational age compared with the last menstrual period date by a median of –1.4 (interquartile range, –4.6, 1.8) days. The Pune fetuses were smaller, even at the first scan, than the urban Vellore sample. ***Conclusions.*** Fetal size was smaller in a rural Indian population than in European and urban Indian populations, even in mid pregnancy. The deficit varied for different fetal measurements; it was greatest for AC and BPD and least for FL and HC. ***Key words:*** fetal growth; fetal sonography; India; population differences.

Abbreviations
AC, abdominal circumference; BMI, body mass index; BPD, biparietal diameter; FL, femur length; HC, head circumference; IQR, interquartile range; IUGR, intrauterine growth restriction; LMP, last menstrual period; OFD, occipitofrontal diameter; PMNS, Pune Maternal Nutrition Study

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Research into the developmental origins of health and disease has focused attention on fetal development as a determinant of lifelong health and capacity. Size and body proportions at birth predict short- and long-term outcomes, from infant mortality[1] through childhood growth and cognitive ability[2,3] to diseases in adult life such as type 2 diabetes and cardiovascular disease.[4,5] Research in this field has relied mainly on studies linking birth weight to outcomes in later life. Birth size, however, is a crude summary measure of fetal

growth, and two neonates of identical birth weight may have followed different fetal growth trajectories.[6] Prospective studies incorporating serial sonographic measurements of fetal size may increase understanding of the fetal origins of health and disease.

Fetal growth differs not only between individuals but also between populations. Indian neonates are among the smallest in the world; mean full-term birth weight is 2.6 to 2.9 kg compared with 3.5 to 3.7 kg for white populations in high-income countries.[7] Indian neonates are not proportionately smaller in all body measurements. A comparison of newborn anthropometric data between the United Kingdom and India showed that although birth weight and abdominal circumference (AC) were lower in the Indian neonates by 1.7 and 2.4 SD, birth length and subscapular skin folds were lower by only 1.0 and 0.5 SD.[8] Studies of fetal growth and its determinants in different populations may therefore provide information on population-specific health problems, such as the current epidemic of type 2 diabetes in India.[9]

The Pune Maternal Nutrition Study (PMNS), based in rural villages near Pune, India, is one of the first prospective studies established specifically to study associations between maternal nutritional status and long-term outcomes in the offspring.[8,10] Fetal size was measured serially by sonography in more than 800 pregnancies. This article is the first in a series exploring fetal growth patterns, their determinants, and their associations with health outcomes in the children. Because there is little published data from India, we first present simple descriptive data on fetal sonographic measurements and a comparison with a European population.

Materials and Methods

The PMNS methods have been described previously.[8,10] In brief, married women of childbearing age (15–40 years; n = 2675) were identified by a survey of 6 villages located 40 to 50 km from the city of Pune. Most families lived by subsistence farming on small landholdings, and most of the women were vegetarian, had low energy and protein intakes, and did farming work in addition to domestic chores. Nonpregnant women were enrolled in 1994 to 1996, and 2466 (92%) agreed to participate. Their weight and height were measured, and they were visited monthly by trained health workers to record menstrual period dates. The health workers were girls with 8 to 10 years of schooling recruited from the same villages to ensure rapport with the women. They were trained to ask probing questions, using the religious calendar and local events, to aid the women's recall and obtain the most accurate possible menstrual dates. Women who missed a period had an ultrasound scan 15 to 18 weeks after the last menstrual period (LMP) date to confirm pregnancy.

Sonographic Measurements

Ultrasound scans were performed by 1 of 2 trained sonologists (A.S.N. and M.C.C.) using a portable machine with a curvilinear 5-MHz transducer (SSD-500 version 8.1, Aloka Co, Ltd, Osaka, Japan) carried in a customized van that visited each village weekly. Biparietal diameter (BPD) was measured at the level of the thalami and cavum septum pellucidum from the outer table of the proximal calvarium to the inner table of the distal calvarium.[11,12] Occipitofrontal diameter (OFD) was measured at the same level, and head circumference (HC) was calculated by the formula (BPD + OFD) × 1.62. Abdominal circumference was calculated as (transverse diameter + anteroposteror diameter) × 1.57 at the level of the umbilical vein–ductus venosus complex.[13] Femur length (FL) was measured along the long axis of the ossified femoral diaphysis with both the femoral head and distal epiphysis visible, although not included in the measurement.[14] The variation attributable to observers ranged from 0.004% to 0.04% for these measurements. Sonographic gestation was calculated as an average of the predicted age derived from the fetal BPD, HC, AC, and FL.[15]

The PMNS was designed to collect fetal growth data at fixed times during gestation (≈18 ± 2 weeks, 28 ± 2 weeks, and 36 ± 2 weeks). For a study of fetal growth, it is important to use LMP dates to derive fetal age rather than sonographic gestation because the latter assumes identical growth in all fetuses and simply translates a measure of size into a gestational age using reference data. Despite monthly visits by the health work-

ers, LMP dates were clearly inaccurate in some women, leading to large discrepancies between LMP-derived and sonographically derived gestational age. For the practical purposes of running the study and scheduling later scans, gestational age at the first visit after a missed period was derived from the LMP date unless it differed from the sonographic estimate by more than 2 weeks, in which case the latter was used. For the purpose of this analysis, we used only gestational ages derived from LMP dates and excluded women whose LMP-derived gestation differed by more than 2 weeks from sonographic gestation (n = 144). Seventeen women were excluded because they had no sonographic or LMP data. Of 1102 women with a confirmed pregnancy, 288 were excluded because of spontaneous or medical abortion, multiple pregnancy, or fetal anomalies on sonography or because the pregnancy was too advanced (>20 weeks). The final sample size was 653. Of these, 372 mothers (57%) had 3 scans; 228 (35%) had 2 scans; and 53 (8%) had only 1 scan; 653 attended the first scheduled appointment; 587 attended the second; and 385 attended the third. The median (interquartile range [IQR]) gestational ages at the 3 examinations were 17 (17, 18), 29 (29, 30) and 35 (34, 36) weeks, respectively.

Most deliveries occurred at home in the villages. Health workers performed detailed newborn anthropometric examinations within 72 hours of birth, using standardized protocols adapted from reference techniques used in children[16,17] to measure weight, crown-rump length, triceps and subscapular skin fold thickness, and mid–upper arm circumference, occipitofrontal HC, and AC. Interobserver and intraobserver variation studies and retraining sessions were performed for all health workers at 6-month intervals.

Permission for the study was granted by village elders and by the Research Ethics Committee of the King Edward Memorial Hospital at Pune. Informed consent was obtained from the women.

Statistical Analysis

The approach outlined by Royston[18] was used to construct fetal growth curves. The model formulation was a sequential process. A power ($\hat{\lambda}$) for the transformation of each fetal dependent variable (Y) was estimated by a Box-Cox regression procedure. We then used regression to estimate a suitable function of gestational age $X = g(T)$ for Y and Y^{λ} such that each individual's response variable was approximately linear. For the function $g(T)$, a family of second-degree fractional polynomial functions was considered, and the model with the lowest deviance was selected.[19] The usefulness of the Y transformation in reducing residual non-normality and heteroscedasticity was assessed by a pseudo F test. The following multilevel model was then fitted by a restricted maximum-likelihood algorithm. The following multilevel model (multilevel because we had repeated measures from each fetus) for each fetal size component was then fitted by a restricted maximum likelihood algorithm:

$$Y_{ij}^{\lambda} = \beta_0 + \mu_{0i} + (\beta_1 + \mu_{1i})\, g(T_{ij}) + \varepsilon_{ij},$$

where, Y_{ij}^{λ} was the transformed response of HC, BPD, AC, and FL, and $g(T_{ij})$ was the covariate function of gestational age for fetus i at observation j. β_0 and β_1 were the fixed intercept and slope, respectively; μ_{0i} and μ_{1i} were the random intercept and slope coefficients for each fetus (j); and ε_{ij} was the leftover error term for fetus i at observation point j. Predicted means and growth curves with a 95% reference interval were plotted from the final models. Results from the model-fitting process and parameter estimates to recreate the growth curves are presented in Table 1.

To test the reliability of the growth curves, models were fitted in another sample of 153 fetuses from mothers in the same community who had ultrasound scans within 10 weeks of their LMP as part of another study. The growth curves in this subset were similar to those reported in this study. Furthermore, the coefficients to indicate the data source were nonsignificant ($P > .05$, Wald test) in the growth models using the pooled data sets.

We compared the PMNS data with fetal sonographic data from a large French population-based study in which fetal measurements were made by similar techniques.[20] The Pune fetal measurements were estimated and plotted in z-standardized units referenced to this cohort. We also made a comparison with an urban south Indian cohort (Vellore).[21] No equations for the

growth curves were provided in this paper, so we restricted our comparisons to the tabulated median, 10th, and 90th percentiles at 20, 28, and 36 weeks provided by the authors. Information on HC was also not available for this cohort. Patterns of fetal growth were similar in male and female fetuses, so the data were pooled. Pooling also allowed a direct comparison with the reference populations.

Mean values for birth weight and birth length at full term (40 weeks) in this population were obtained by adjusting measurements at birth for gestation in completed weeks using linear regression.

Results

The PMNS mothers were short, light, and thin (mean height and body mass index (BMI), 152 cm and 17.9 kg/m^2, respectively; Table 2); 64% were underweight (<18.5 kg/m^2).[22] Most were younger than 22 years, and approximately one-third were primiparous. The mean birth weight was 2609 g; 32% were classified as low birth weight (<2500g), and 11% were born before term (<37 weeks' gestation).

The mean birth weight adjusted to 40 weeks was 2718 g (SD, 337 g). Although direct comparisons against the reference populations were not possible, in a contemporaneous cohort of 58,834

Table 1. Results From the Model-Fitting Process and Parameter Estimates to Recreate the Growth Charts

	Y			
	HC	**BPD**	**AC**	**FL**
Model fitting				
$\hat{\lambda}$	0.73	0.58	0.32	1.0
95% CI	(0.66–0.81)	(0.51–0.65)	(0.26–0.39)	(0.96–1.06)
$\hat{\lambda}$ rounded	0.75	0.6	0.3	1.0
$\hat{\lambda}$ final	0.75	0.6	0.3	1.0
Untransformed *Y*				
G(*T*)	$T^2 - 0.01752\ T^3$	$T^3\ (1 - 0.25328 \ln T)$	$T^3\ (1 - 0.24754 \ln T)$	$T^{-2}\ (1 - 0.45866 \ln T)$
Transformed *Y* (Y^{λ})				
G(*T*)	**$T^2 - 0.01789\ T^3$**	**$T^2 - 0.01787\ T^3$**	**$T^{-2}\ (1 - 0.48246 \ln T)$**	NT
For transformation				
F_{trans}	18.97	50.83	114.7	NT
Parameter estimates				
$\hat{\mu}$	2.3352	1.0889	3.2996	10.9676
$\hat{\beta}$	0.02302	5.259×10^{-3}	986.5059	8410.0829
$\hat{\sigma}^2_{\mu}$	0.1284	0.01184	2.8832×10^{-3}	0.095506
$\hat{\sigma}^2_{\beta}$	5.004×10^{-7}	6.375×10^{-8}	2296.5523	97444.34
$\hat{\sigma}^2_{\mu\beta}$	1.8721×10^{-4}	2.206×10^{-5}	1.9713	77.5027
$\hat{\sigma}^2_{\varepsilon}$	0.05187	2.8262×10^{-3}	7.6017×10^{-4}	0.01283

Notation is per Royston.[18] Powers ($\hat{\lambda}$) for the transformation of fetal measurements (*Y*) were estimated using the Box-Cox regression procedure in Stata version 10 and rounded to the nearest 0.05 ($\hat{\lambda}$ rounded) or 1 if the 95% CI overlapped 1 (no transformation [NT]). The covariate functions for gestational age in weeks [*g*(*T*)], selected from a family of second-order fractional polynomials,[19] are presented. The effect of $\hat{\lambda}$ rounded in reducing residual non-normality and heteroscedasticity was assessed using an *F* test (F_{trans}). High *F* values (>3) indicate that the transformation of *Y* improves the residual diagnostics and so dictated the choice of a transform of *Y* ($\hat{\lambda}$ final). Bold values indicate the final covariate function used to transform gestational age. The parameter estimates can be used to recreate the growth profiles and reference intervals. The mean $E(Y^{\lambda})$ and variance, $var(Y^{\lambda})$, of the transformed fetal measurement are given by

$$E(Y^{\lambda}) = \mu_z = \mu + \beta g(T)$$

$$var(Y^{\lambda}) = \sigma_z^2 = \hat{\sigma}^2_{\mu} + g(T)^2\hat{\sigma}^2_{\beta} + 2\ g(T)\ \hat{\sigma}^2_{\mu\beta} + \hat{\sigma}^2_{\varepsilon}\ .$$

The desired reference interval can then be calculated using the normal distribution function; for example, a 95% reference range would be given by $(\mu_z \pm 1.96\ \sigma_z)^{1/\lambda}$

neonates from the same region as the French fetal data,[23] the mean birth weight at 40 weeks was 3477 g (SD, 409 g). In the south Indian urban study, the median birth weight was 3000 g (this estimate was likely to have been larger if we had the adjusted value at 40 weeks). Newborn size was therefore smaller in the Pune population than in both the French and Vellore populations. The mean adjusted birth lengths at 40 weeks were 48.1 cm (SD, 1.99 cm) in the PMNS sample and 50.5 cm (SD, 1.82 cm) in the French geographically matched sample. In standardized units, the Pune neonates were 1.86 and 1.32 SD below the French weight and length references, respectively, at birth.

Tests for Bias in the Sample

There were no significant differences in any of the fetal size variables at the first visit when comparing fetuses that had 3 scans versus those that had less than 3 scans (P = .6–.95 for all comparisons, adjusted for gestational age) and no significant differences in birth weight, length, and AC between those with differing numbers of scans (P = .084–0.25).

Statistical Description of Models

A transformation was deemed necessary to improve the model fit of all of the fetal measurements except FL (Table 1). The models and residuals were a good fit; the proportion of observations outside the 95% reference interval ranged from 4.2% to 4.7%.

Although there was tracking in the growth curves, there was still substantial percentile crossing. This was evident in the intraclass correlation coefficients, which reflected the amount of within-subject correlation in SD scores across gestation. The intraclass correlation coefficients (95% confidence intervals) for HC, BPD, AC, and FL were 0.47 (0.42, 0.53), 0.49 (0.43, 0.54), 0.51 (0.46, 0.56), and 0.62 (0.58, 0.66), respectively.

Comparison of Growth Curves With the European Population

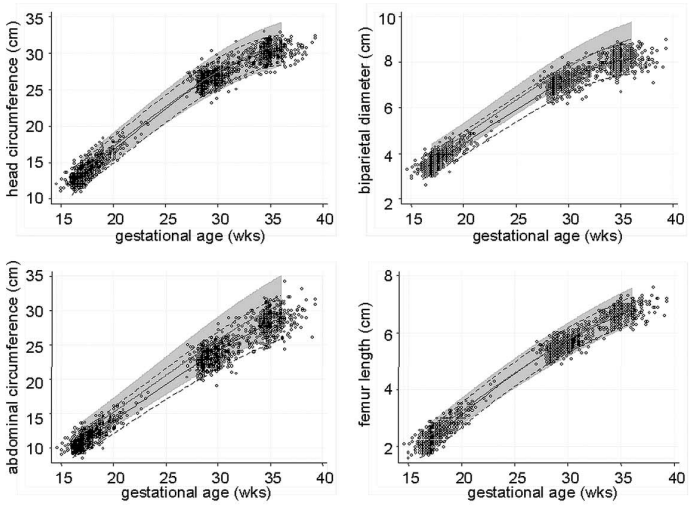
Mean BPD and AC in the PMNS were smaller than in the European sample, even at the first ultrasound scan (Figure 1 and Table 3), whereas HC and FL values were closer to the European values. All measurements were smaller in late pregnancy, and there was a hierarchy: the greatest relative disparities were in AC (median, 29.0 versus 31.0 cm) and BPD (8.1 versus 9.0 cm) at 36 weeks.

Table 2. Characteristics of the Cohort

Characteristic	n	Value
Fetus at birth		
Male[a]	626	340 (54.3)
Birth weight, g[b]	576	2609 (398)
Low birth weight (<2500 g)[a]	576	183 (32)
Birth length, cm[b]	596	47.4 (2.34)
HC, cm[b]	597	32.9 (1.47)
AC, cm[b]	597	28.4 (2.1)
Gestational age, wk[c]	627	39.1 (38.1, 40.3)
Premature (<37 wk)[a]	627	69 (11)
Mother		
Age, y[c]	653	21 (19, 23) (range, 15–40)
Parity[a]		
0	653	210 (32)
1–3		415 (64)
≥4		28 (4.3)
Height, cm[b]	653	151.9 (5.0)
Weight, kg[b]	647	41.7 (5.0)
BMI, kg/m^2[c]	647	17.8 (16.7, 19.1)
Father		
Height, cm[b]	610	164.5 (6.1)
Weight, kg[b]	614	52.6 (7.8)
BMI, kg/m^2[c]	609	19.0 (17.6, 20.7)

[a]Values are number (percent).
[b]Values are mean (SD).
[c]Values are median (IQR).

Figure 1. Plots of HC, BPD, AC, and FL with the fitted prediction lines and 95% reference ranges. The shaded areas represent the 95% reference ranges and means from the western European cohort.



The differences in the relative sizes of the fetal components are shown more clearly when the PMNS values are plotted as standardized scores on the European reference (Figure 2). Mean HC and FL tracked between the 22nd and 45th percentiles of the European reference from 18 to 35 weeks. Mean BPD tracked below the 10th percentile of the European distribution over gestation, and AC tracked between the 8th and 16th percentiles.

Comparison With the South Indian Urban Cohort

Compared with data from Vellore, the PMNS fetuses were smaller at all time points in gestation, with marked differences in BPD and AC evident even at 20 weeks (Table 3).

Gestational Dating and Intrauterine Growth Restriction

The equations of Hadlock et al[15] to date pregnancies from 4 sonographic measurements systematically underestimated gestational age compared with LMP dating (median difference at 18 weeks, –1.35 days; IQR, –4.60, 1.77 days; signed ranks test, $P < .001$. Defined as AC below the 10th percentile of the European reference, 54% of the fetuses had intrauterine growth restriction (IUGR) at the first visit (~18 weeks), 36% at the second (~28 weeks), and 30% at the third (~35 weeks).

Discussion

To our knowledge, a study presenting sonographically derived measurements of fetal growth from a rural Indian cohort and comparing them against a western population has not been reported previously. Fetal AC and BPD were markedly smaller than the western references at 18 weeks; gestation, whereas FL and HC were comparable. In late pregnancy (28 and 36 weeks), all measurements were smaller than the European references. The deficit was greatest for AC and BPD (the latter becoming smaller relative to the European population as pregnancy progressed). The PMNS fetal size measurements were also small compared with an urban South Indian study.

Strengths of the study were that it was population based and, with the use of a portable machine, collected serial sonographic data on a representative sample from a rural population. Measurements were made according to standardized protocols by 2 experienced medical sonologists, ensuring high-quality measurements and minimizing "noise" due to interobserver variation. There are few studies with carefully collected LMP data based on regular monthly visits in a population like this. However, despite the care taken, 144 women were excluded from the analysis because of an implausibly

Table 3. Predicted 10th, 50th, and 90th Percentiles of Fetal Size at 20, 28, and 36 Weeks' Gestation

	Pune			European			Vellore[a]		
Fetal Measurement	**10th**	**50th**	**90th**	**10th**	**50th**	**90th**	**10th**	**50th**	**90th**
20 wk									
HC, cm	15.5	16.7	17.9	15.9	17.1	18.4	ND	ND	ND
BPD, cm	4.1	4.4	4.8	4.4	4.8	5.1	4.4	4.8	5.3
AC, cm	12.7	13.9	15.2	13.8	15.2	16.5	12.9	14.6	16.8
FL, cm	2.8	3.1	3.4	3.0	3.2	3.5	3.0	3.3	3.8
28 wk									
HC, cm	24.2	25.5	26.8	24.1	25.7	27.3	ND	ND	ND
BPD, cm	6.4	6.8	7.2	6.8	7.2	7.7	6.6	7.4	7.7
AC, cm	20.6	22.2	23.9	21.7	23.7	25.7	19.9	22.9	25.5
FL, cm	5.0	5.3	5.6	5.0	5.3	5.7	5.0	5.5	6.1
36 wk									
HC, cm	29.1	30.4	31.8	29.3	31.2	33.2	ND	ND	ND
BPD, cm	7.7	8.1	8.6	8.5	9.0	9.5	8.2	8.7	9.3
AC, cm	26.9	29.0	31.1	28.3	31.0	33.7	27.3	29.5	32.6
FL, cm	6.5	6.8	7.1	6.5	6.9	7.3	6.4	7.0	7.3

ND indicates not determined.
[a]Actual percentiles.

discrepant date relative to sonographic measurements of fetal size. Conception dating during the first cycle after stopping oral contraceptive pills can be unreliable, but none of the women in the study were taking oral contraceptive pills. The study was not designed to generate fetal growth reference curves, which are ideally based on cross-sectional data collected evenly throughout pregnancy[24,25] rather than at 3 time points as in the PMNS. However, there was no evidence of bias in terms of the contribution of repeated measurements to the growth plots; therefore, we have presented the fetal growth equations (Table 1) as a potentially useful reference.

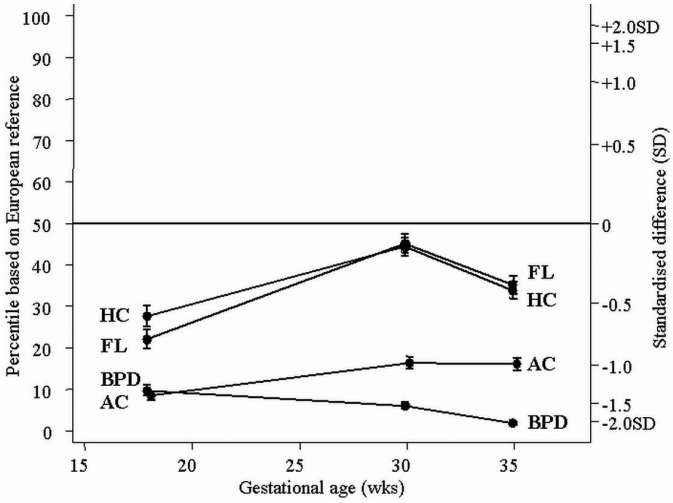
To our knowledge, data showing that Indian fetuses, at least in this rural population, are smaller than European fetuses even at 18 weeks' gestation have not been reported previously. It is generally thought that the small size of Indian neonates at birth is attributable to small maternal size, an inadequate nutrient supply during mid to late pregnancy (due to maternal undernutrition and/or placental insufficiency), or both but that early fetal growth, when nutrient requirements are very small and there are no constraints on space for growth, is similar to that of other populations.[21] This suggests that any interventions to increase fetal growth in rural Indian populations would need to occur before conception or during early pregnancy.

The data suggest a hierarchy within the different fetal components and tissues; femur growth is relatively preserved in Indian fetuses, whereas AC (a combined measure of visceral size and subcutaneous fat) grows more slowly than in European fetuses from early pregnancy. This is consistent with our findings at birth in Indian populations.[8,26] Compared with UK neonates, birth length in the PMNS was relatively preserved (–1.0 SD) compared with birth weight (–1.74 SD) and AC (–2.38 SD). Newborn length was still 4 cm lower at birth than in the UK neonates,[8] suggesting a greater relative deficit in components of fetal length other than FL: for example, the spine or head.

The pattern of growth differed for the two measures of fetal head size in Pune. Although HC was similar to that of the European population in early pregnancy, BPD was markedly smaller. This suggests that the head shape of these fetuses may differ, and OFD may be larger than in European fetuses during early pregnancy. Fetal OFD is not usually reported in the ultrasound literature, so we are unable to confirm this. We do not know the implications of any differences in fetal head shape for brain growth and function.

The PMNS was established to study early life exposures (maternal nutrition, fetal growth, and newborn phenotype) in relation to long-term outcomes (risk of cardiovascular disease and type 2 diabetes). It will therefore take time before the relevance of our findings is known in terms of these clinical outcomes. The main importance of our findings for obstetricians is that the growth of rural Indian fetuses differs from the Western sonographic references that are generally used in clinical practice in India. Hence, gestational age tends to be underestimated, and IUGR is diagnosed very frequently. In our study, the mean difference in gestation between the sonographic and LMP estimates was 1.4 days at approximately 18 weeks, which is unlikely to be of obstetric importance (although it may be of importance for long-term outcomes). The incidence of IUGR was very high (≥30%) throughout gestation, and this is likely to influence pregnancy management, although other sonographic features of IUGR would usually also be considered, such as amniotic fluid volume and umbilical blood flow patterns. Our study was not large enough to

Figure 2. Predicted mean HC, BPD, AC, and FL and their 95% CIs at 18, 30, and 35 weeks' gestation in the Indian cohort plotted as percentiles based on the western European reference.



relate fetal growth patterns to obstetric and perinatal complications (of 770 births after 28 weeks' gestation, there were 8 stillbirths and 8 early neonatal deaths). However, our data suggest the need for a locally generated fetal growth reference, along with prospective data on obstetric and perinatal outcomes, to enable the development of better clinical guidelines for rural populations, which constitute a high proportion of many developing country populations (≈70% in India).

In conclusion, fetal size was smaller in a rural Indian population than in European and urban Indian populations, even during mid pregnancy. The deficit varied for different fetal components, being greatest for AC and BPD and least for FL and HC. Interventions designed to increase fetal growth should start preconceptionally or during early pregnancy. Gestational ages derived from sonographic measurements and Western reference equations are underestimated in this population. Our findings need to be replicated in other Indian populations with data collected earlier in pregnancy. Future analysis of these data will examine determinants of fetal growth, including parental size and maternal nutritional status, and relationships of fetal growth to the newborn condition, postnatal growth, and childhood metabolic status.

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