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Fetal Biometrics

(Dr Mador)

Biometrics is the mathematical study of variation between individuals of a certain species in a population. Information derived from the study of biometrics can give clues to variability, such as whether it is due to heredity or to the environment. Variation or deviation from the standard is a feature of living organisms. No two rabbits or maize grains for example are exactly alike when examined in detail, although in most respects, they may be similar. In fact, it is because of these similarities that we are able to classify living plants and animals into various phyla and genera. Variation is of interest to biologists who, on studying its causes and characteristics, can gain an insight into our past origin and possible future trends. Variation in an organism may be primarily due to heredity, or to environmental influences, or to a combination of the two. Seeds from a common parent plant when sown under different conditions or soil composition can give rise to plants of different health and appearance, although they posses the same genetic constitution. Identical twins with the same genotype, when brought up under difference circumstances, may develop differences in height, weight, behaviour, intelligence and so on. Variation can be of two types; continuous variation or discontinuous variation. In the former, like the height or weight of man, a whole range of intermediate values exist, different only very slightly in magnitude. This continuous variation is not controlled by a single gene but is controlled by the interaction of multiple genes, in addition to influences imposed by the environment. A person may inherit the gene for tallness but if he is undernourished in his initial years of growth, he may not grow as tall as he is expected to. Hence, in man, there is a wide variation in height. In discontinuous variation, there is no gradation of a certain trait. For example, the inheritance of sex in animals is a discontinuous variation. With few exceptions, one is either a male or female and there is no intermediate. In blood grouping, we are members of one of the four groups, A, B, AB or O. Variation of a number of characters in living organisms conforms approximately to a bell-shaped curve or Gaussian (after the mathematician, Gauss) mathematical curve which may be symmetrical or asymmetrical, i.e. skew.

From a random sampling of a large number of human fetuses, the frequency distribution for fetal biparietal diameter, fetal head circumference, fetal occipitofrontal diameter, fetal abdominal circumference, fetal femur length and fetal weight were obtained. The cross-sectional study involved pregnant women with fetuses from 12 – 42 weeks of gestation undergoing ultrasound examination. The study which was carried out in two stages was approved by the Ethics Committee of Jos University Teaching Hospital and before inclusion of the patients, informed consent was obtained. The first stage was mainly for the establishment of normal distribution of fetal parameters. In this stage only singleton pregnancies were included. Pregnant women with concomitant disease possibly affecting fetal growth (e.g. diabetes mellitus, asthma, hypertension, renal disease, thyroid disease) were not included as were those with complications of pregnancy known at the moment of the ultrasound scan (e.g. bleeding, pre-eclampsia). If a fetal malformation was detected during the examination the patient was excluded. Patients with a history of obstetric complications, intrauterine growth retardation or macrosomia were also excluded. The investigator did not take into account complications or diagnosis that occurred later in the pregnancy, after the ultrasound measurements were performed. Every fetus was measured and included only once so that a pure cross-sectional set of data was constructed. For each patient the gestational age was recorded, as were last menstrual period, maternal age and parity. Maternal age was calculated in completed years at the moment of the ultrasound. The subject to be scanned had to lie on the examination couch such that she is able to see the screen easily. Most scans were performed with the patient supine. However, in later pregnancy many patients feel dizzy in this position and it was necessary for such patients to be tilted to one side. This is easily achieved by placing a pillow under one of the buttocks. The patient had to be uncovered just sufficiently to allow the examination to be performed. This will include the first inch of the area covered by the pubic hairs and will extend far enough upwards to allow the fundus of the uterus to be visualized. A full bladder was the only prerequisite for an ultrasound examination.

All the fetal biometric measurements were performed using Philips Real time ultrasound machine equipped with 3.5MHz transducer and an electronic caliper system set at a velocity of 1540m/s. Fetal head measurements were made in an axial plane at the level where the continuous midline echo is broken by the cavum septum pellucidum in the anterior third and that includes the thalamus. This transverse section should demonstrate an oval symmetrical shape. Measurement of BPD was from the outer edge of the closest temporomandibular bone to the outer edge of the opposite temporomandibular bone. Measurement of OFD was from the outer edge of the frontal bone to the outer edge of the occipital bone. The HC was measured around the calvarium from the same axial image as for the BPD. The abdominal circumference was measured through the transverse section of the fetal abdomen at the level of the stomach and bifurcation of the main portal vein into its right and left branches. The femur length was measured from the greater trochanter to the lateral condyle, with both ends clearly visible and at a horizontal angle $<45^0$. All measurements were expressed in millimeters. Estimated fetal weight was calculated in grams by the formulae described by Shepard and by Hadlock, as these are included in the software of most commercially available ultrasound scanners (Shepard *et al*., 1982).

The second stage of the study involved blood sample collection from women who were not pregnant and those women with normal singleton/multiple pregnancies. Estimated age of pregnancy was determined using ultrasound machine and compared with age calculated from last menstrual period. The

Venous blood samples were collected from the non-pregnant women and pregnant women at various gestational ages into plain vacutainers and serum removed from cells by centrifugation as quickly as possible. This prevents possible dilution by intracellular contents. Grossly lipaemic and significantly haemolysed samples (concomitant glutathione release leads to low values) were not used. Samples were stored refrigerated for 3 – 5 days (Tietz, 1995) until analyzed for uric acid in batches and protein free filtrate used. Uricase method (Urate Oxidase, EC 1.7.3.3), the enzyme that catalyses the oxidation of Uric Acid to Allantoin which is more specific was used. The Uricase Method measures the differential absorption of Uric Acid and Allantoin at 293nm (Feichtmeier and Wrenn, 1995). The difference in absorbance before and after incubation with Uricase is proportional to the Uric Acid in a protein free filtrate, with subsequent reduction of phosphotungstic Acid to tungsten blue with sodium carbonate providing the alkaline necessary for colour development (Caraway, 1965). Each assay was validated using commercial quality control samples, standards as well as previously assayed human sera. Samples were also duplicated in-between batches. Data were then subjected to descriptive statistical analysis.

Biometrics of Fetal Head Circumference

Fetal head circumference measurements were classified into thirty one groups (Tab. 6.1). The group with the highest number of observations was from 34 to 34 + 6 while 42 to 42+6 group had the lowest number of observations. Marked variability in the measurements was seen in groups 18 to 18+6, 29 to 29+6 and 40 to 42+6. In group 13 to 13+6, variation in the measurements was minimal. Standard error of mean of head circumference measurements from 12 – 42 weeks gestation was found to be less than 1 with the exception of groups 12, 18 and 29 where the standard error of mean is above 1.

The geometric mean values of head circumference measurements as seen in Tab. 6.2 were found to be less than their arithmetic means but greater than their harmonic means indicating that all the fetal head circumference measurements were not identical. The centile values of fetal head circumference measurements from 12 – 42 weeks gestation are as shown in Tab. 6.3. This table gives the 3rd, 5th, 10th, 50th, 90th, 95th, and 97th centile values for fetal head circumference measured at different gestational age ranging from 12 – 42 weeks. For example, it can be seen from the table that the 10th percentile of head circumference at 18 to 18 + 6 weeks gestation is 146 millimeters. This means that 10% of the fetuses in Jos at 18 to 18 + 6 had a mean head circumference less than 146 millimeters, while 90% had a mean head circumference greater than 146 millimeters. Similarly, the 97th percentile of head circumference at 39 to 39 + 6 is 378 millimeters. Hence 97% of fetuses at 39 to 39 + 6 had a mean head circumference less than 378 millimeters while 3% had a mean head circumference greater than 378 millimeters.

The standard score or z-score of head circumference measurements in 13,740 fetuses in Jos ranging from 12 – 42 weeks of gestation is as shown in Tab. 6.4. The z-score enables one to look at head measurements at each gestational age and see how they compare on the same standard; taking into account the mean and standard deviation of each gestational age. For example, head circumference measurements at 12 weeks are – 0.002 standard deviations from the mean while measurements at 14 weeks are 0.003 standard deviations from the mean. Again, from the above z-score table, it can be seen that the head circumference measurements at 20 and 38 weeks are 0.000 deviations from the mean.

While comparing the z-score at 12, 14, 20 and 38 weeks of gestation, it can be seen that z-score at 14 weeks gestation is higher followed by 20 weeks while at 12 weeks it is much lower because it is negative (-0.002).

Tab. 6.1 *Frequency distribution table of fetal head circumference measurements showing arithmetic mean, standard deviation and standard error of mean from 12 – 42 weeks gestation.*

GA (week, days)	Number of fetuses (n)	Mean HC (mm)	SD	SEM
12 to 12+6	49	80.9	10.5	1.5
13 to 13+6	384	94.1	9.6	0.5
14 to 14+6	371	108.6	11.8	0.6
15 to 15+6	351	122.5	13.8	0.7
16 to 16+6	505	133.0	9.7	0.4
17 to 17+6	427	146.1	10.9	0.5
18 to 18+6	446	162.1	23.5	1.1
19 to 19+6	282	169.4	15.2	0.9
20 to 20+6	553	180.7	12.7	0.5
21 to 21+6	400	193.0	11.7	0.6
22 to 22+6	398	201.9	11.3	0.6
23 to 23+6	478	212.7	13.9	0.6
24 to 24+6	520	225.8	13.3	0.6
25 to 25+6	388	238.7	14.0	0.7
26 to 26+6	511	249.3	15.2	0.7
27 to 27+6	432	260.0	15.4	0.7
28 to 28+6	548	269.1	13.3	0.6
29 to 29+6	484	274.2	23.3	1.1
30 to 30+6	625	284.9	17.0	0.7
31 to 31+6	523	292.2	14.9	0.7
32 to 32+6	583	299.5	14.7	0.6
33 to 33+6	516	306.9	12.9	0.6
34 to 34+6	744	314.6	15.0	0.6
35 to 35+6	739	318.8	13.5	0.5
36 to 36+6	599	324.9	14.7	0.6
37 to 37+6	532	330.9	13.7	0.6
38 to 38+6	481	337.6	15.1	0.7
39 to 39+6	525	342.9	14.4	0.6
40 to 40+6	252	345.2	14.1	0.9
41 to 41+6	72	349.6	11.8	1.4
42 to 42+6	22	347.4	23.6	5.5
Total	13740			

***Tab. 6.2** Frequency Distribution Table of Fetal Head Circumference Measurements Showing Arithmetic mean, Geometric mean and Harmonic mean from 12 – 42 weeks Gestation.*

GA (week, days)	Number of fetuses (n)	Arithmetic mean (mm)	Geometric mean (mm)	Harmonic mean (mm)
12 to 12+6	49	80.87755	80.19505	79.49107
13 to 13+6	384	94.08594	93.57099	93.02122
14 to 14+6	371	108.6388	108.0839	107.5773
15 to 15+6	351	122.4758	121.847	121.3091
16 to 16+6	505	132.9644	132.612	132.2597
17 to 17+6	427	146.1148	145.7095	145.3004
18 to 18+6	446	162.1435	160.8212	159.7357
19 to 19+6	282	169.3652	168.754	168.1866
20 to 20+6	553	180.6998	180.2787	179.8754
21 to 21+6	400	192.9975	192.6456	192.2944
22 to 22+6	398	201.8869	201.58	201.2776
23 to 23+6	478	212.7113	212.2518	211.7762
24 to 24+6	520	225.8308	225.4465	225.0655
25 to 25+6	388	238.6649	238.2416	237.7988
26 to 26+6	511	249.2681	248.8127	248.3601
27 to 27+6	432	260.0023	259.5373	259.0611
28 to 28+6	548	269.135	268.7951	268.4434
29 to 29+6	484	274.2252	272.6465	269.6992
30 to 30+6	625	284.8512	284.3175	283.7497
31 to 31+6	523	292.1931	291.7838	291.3389
32 to 32+6	583	299.5266	299.1455	298.7357
33 to 33+6	516	306.8663	306.5755	306.2606
34 to 34+6	744	314.5565	314.1824	313.7874
35 to 35+6	739	318.7767	318.4873	318.1912
36 to 36+6	599	324.9232	324.5829	324.2289
37 to 37+6	532	330.8741	330.5896	330.302
38 to 38+6	481	337.6008	337.2799	336.973
39 to 39+6	525	342.8629	342.5604	342.2585
40 to 40+6	252	345.2064	344.9261	344.6524
41 to 41+6	72	349.5555	349.3567	349.1544
42 to 42+6	22	347.3636	346.5916	345.81
Total	13740			

Tab. 6.3 *Centiles of fetal head circumference measurements.*

	Head circumference centiles (mm)						
Gestational age	**3rd**	**5th**	**10th**	**50th**	**90th**	**95th**	**97th**
12 to 12+6	56.0	61.5	69.0	79.0	96.0	98.5	101.0
13 to 13+6	75.0	78.0	82.0	94.0	106.0	108.0	109.0
14 to 14+6	92.2	94.0	96.0	108.0	118.8	122.0	126.0
15 to 15+6	104.6	110.0	111.0	120.0	134.0	141.0	155.4
16 to 16+6	116.0	119.0	121.0	133.0	145.0	149.0	151.0
17 to 17+6	122.7	130.0	135.0	146.0	159.0	163.0	170.0
18 to 18+6	131.0	134.0	146.0	159.0	172.2	196.2	203.0
19 to 19+6	140.0	150.0	156.3	168.0	183.0	191.9	200.5
20 to 20+6	160.0	164.0	169.0	180.0	195.0	201.0	210.0
21 to 21+6	171.0	175.0	181.0	193.0	206.9	214.0	222.0
22 to 22+6	181.0	186.0	190.0	201.0	215.0	220.1	223.0
23 to 23+6	183.0	191.0	199.0	212.0	227.0	233.0	239.6
24 to 24+6	200.0	205.0	214.0	225.0	239.9	247.0	250.0
25 to 25+6	206.4	216.5	225.9	238.0	253.0	261.7	265.0
26 to 26+6	220.0	226.0	232.2	249.0	265.0	272.0	279.0
27 to 27+6	230.0	232.7	240.3	260.0	278.0	287.0	292.0
28 to 28+6	243.0	247.0	255.0	270.0	284.0	289.0	292.0
29 to 29+6	229.2	246.3	260.0	277.0	290.0	294.0	302.0
30 to 30+6	250.0	262.3	269.0	286.0	300.0	309.0	315.4
31 to 31+6	253.0	267.0	276.0	293.0	309.0	311.0	314.3
32 to 32+6	274.1	279.2	284.4	300.0	316.0	320.0	322.0
33 to 33+6	280.0	286.0	293.0	308.0	321.0	324.0	328.0
34 to 34+6	286.0	290.5	300.0	315.0	330.5	335.0	340.0
35 to 35+6	291.2	297.0	301.0	320.0	333.0	338.0	340.8
36 to 36+6	301.0	303.0	306.0	326.0	339.0	346.0	351.0
37 to 37+6	300.0	302.7	312.3	333.0	344.7	351.0	358.0
38 to 38+6	310.9	315.0	320.0	337.0	352.0	359.0	364.0
39 to 39+6	318.0	320.3	326.2	342.0	359.0	372.0	378.0
40 to 40+6	323.0	324.3	330.0	344.0	360.0	373.5	382.5
41 to 41+6	316.0	329.0	335.0	348.5	366.0	366.0	367.6
42 to 42+6	306.0	306.0	306.0	353.0	387.0	387.0	387.0

Tab. 6.4 *Standard score (z-score) of head circumference measurements in 13,740 Nigerian fetuses in Jos ranging from 12 – 42 weeks gestation.*

GA (weeks, days)	Fetuses (n)	Mean z-score
12 to 12+6	49	-2.14E-03
13 to 13+6	384	-1.46E-03
14 to 14+6	371	3.29E-03
15 to 15+6	351	-1.75E-03
16 to 16+6	505	-3.67E-03
17 to 17+6	427	1.35E-03
18 to 18+6	446	1.85E-03
19 to 19+6	282	-2.29E-03
20 to 20+6	553	-1.42E-05
21 to 21+6	400	-2.14E-04
22 to 22+6	398	-1.16E-03
23 to 23+6	478	8.13E-04
24 to 24+6	520	2.31E-03
25 to 25+6	388	-2.50E-03
26 to 26+6	511	-3.48E-03
27 to 27+6	432	1.50E-04
28 to 28+6	548	2.63E-03
29 to 29+6	484	1.08E-03
30 to 30+6	625	-2.87E-03
31 to 31+6	523	-4.62E-04
32 to 32+6	583	1.81E-03
33 to 33+6	516	-2.61E-03
34 to 34+6	744	-2.90E-03
35 to 35+6	739	-1.72E-03
36 to 36+6	599	1.58E-03
37 to 37+6	532	-1.89E-03
38 to 38+6	481	5.51E-05
39 to 39+6	525	-2.58E-03
40 to 40+6	252	4.50E-04
41 to 41+6	72	-3.77E-03
42 to 42+6	22	-1.56E-03
Total	13740	

When head circumference data of 13,740 Nigerian fetuses in Jos was subjected to skewness analysis at different gestational age ranging from 12 – 42 weeks (Fig. 6.1), it was found that the distribution of head circumference measurements has a longer "tail" to the right of the central maximum than to the left or is skewed to the right from 13 – 24 weeks. From 25 – 37weeks, the distribution has a longer "tail" to the left of the central maximum than to the right or is skewed to the left. By the time pregnancy reaches term, the distribution becomes skewed to the right before skewing again to the left as from 41 weeks. When the head circumference data was subjected to kurtosis analysis (Fig. 6.2), the analysis was found to be leptokurtic at 14, 15, 18, 19, 29. 33 and 38 weeks of gestation while at 12, 13, 16,17, 20, 21, 22, 23, 24, 25, 26, 27, 28, 20, 31, 32,34, 35, 36, 39, 40, 41 and 42 weeks of gestation, the kurtosis was mesokurtic. The coefficient of dispersion of head circumference data of 13,740 fetuses in Jos at different gestational age shows a decrease in value as gestational age advances except at 18, 23, 25, 26, 29, 30 and 42 weeks where it peaks (Fig. 6.3). The head circumference scattergram in Fig.6.4 shows that there are very few bad data points or outliers in the head circumference measurements of 13,740 fetuses in Jos. The outliers are more from 26 – 42 weeks of gestation. This shows the pattern of growth recognized for neural tissue which suggests growth of brain.

In Fig. 6.5, mean head circumference is plotted against gestational age with error bars showing standard deviation. Mathematical modeling of head circumference data plotted against gestational age demonstrated that the best-fitted regression model (Fig. 6.6) to describe the relationship between head circumference and gestational age was the third order polynomial regression equation $y = -0.0029x^3 + 0.0518x^2 + 13.136x - 78.198$ with a correlation of determination of $R^2 = 0.9996$ ($P < 0.0001$) where y is the head circumference in millimeters and x is the gestational age in weeks. This means that head circumference could predict the gestational age of fetuses in Jos by 99.96 percent

(R^2 = 0.9996) in 13,740 fetuses in this study.

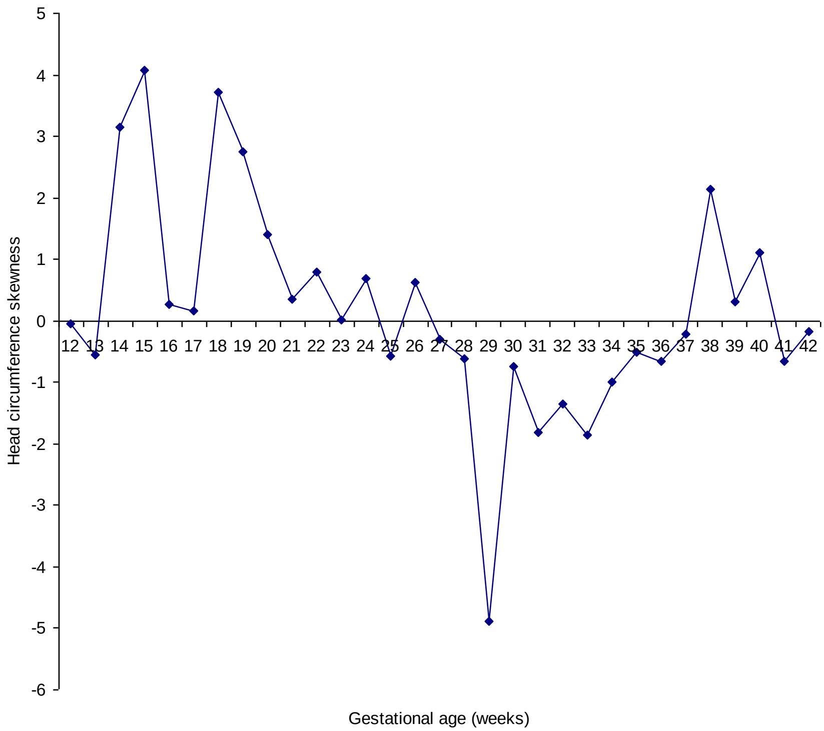

Fig. 6.1 *Head Circumference data of 13,740 Fetuses Subjected to Skewness Analysis at Different Gestational Age Ranging from 12 – 42 weeks.*

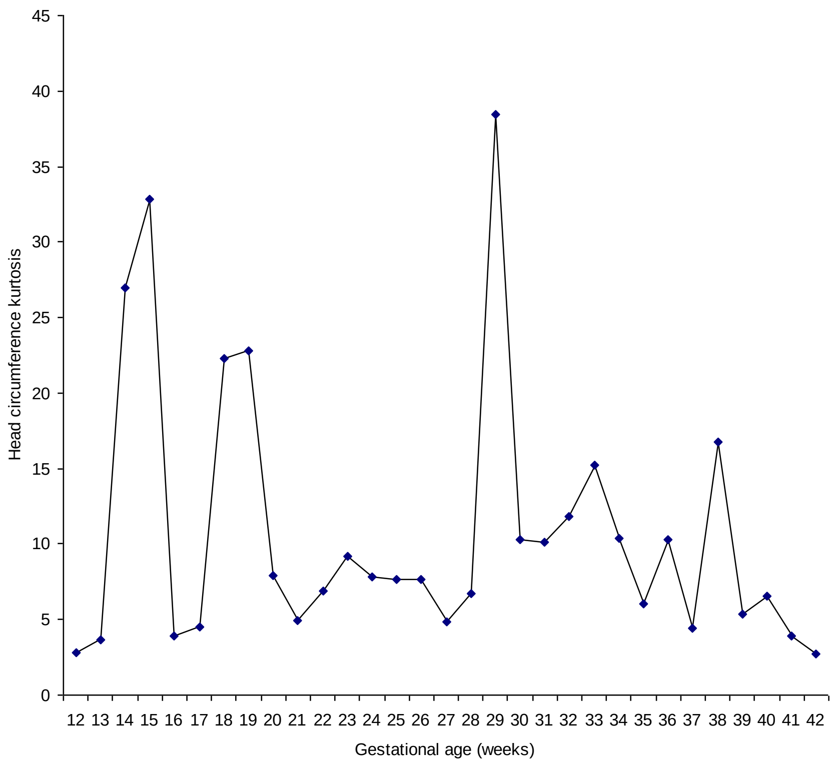

Fig. 6.2 *Head circumference data of 13,740 fetuses subjected to kurtosis analysis at different gestational age ranging from 12 – 42 weeks.*

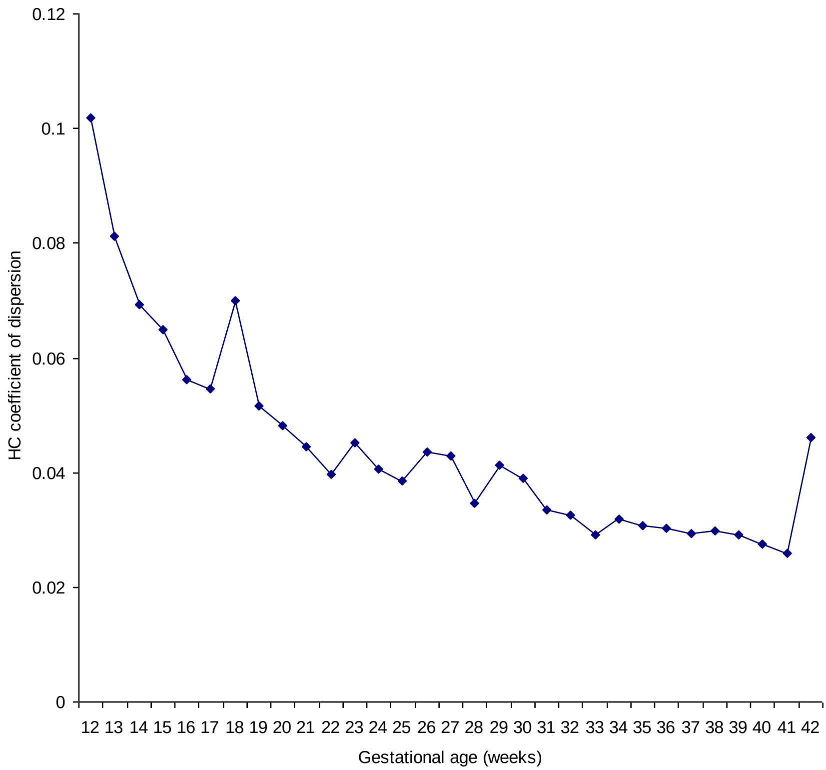

Fig. 6.3 *Head circumference coefficient of dispersion in 13,740 fetuses of gestational ages between 12 to 42 weeks.*

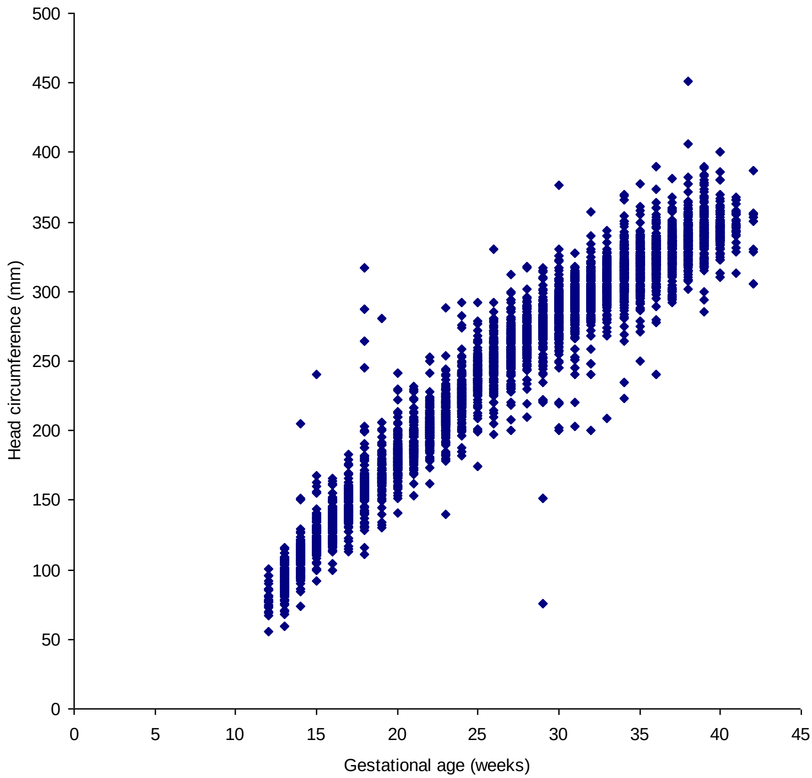

Fig. 6.4 *Scattergram of 13,740 fetal head circumference measurements from 12 – 42 weeks gestation.*

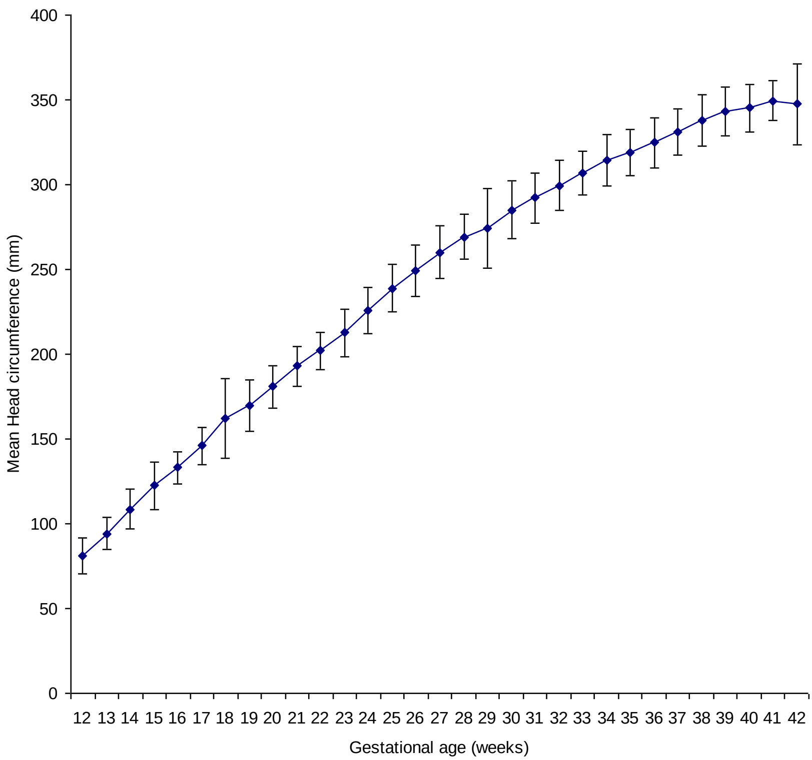

Fig. 6.5 *Mean fetal head circumference values in 13,740 fetuses of women at different gestational ages between 12 – 42 weeks. The vertical bars show the values of ±SD.*

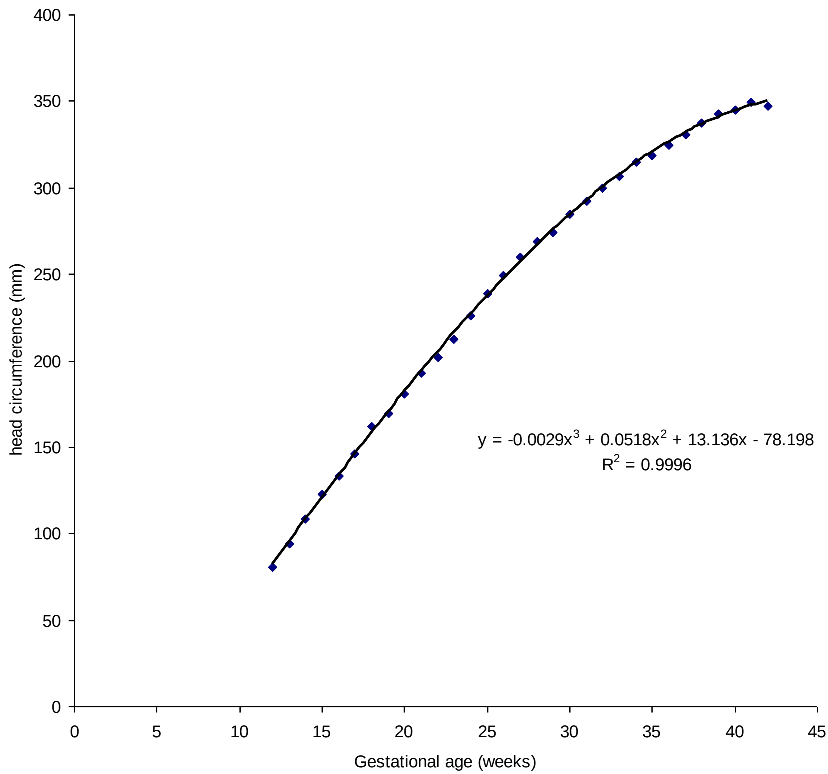

Fig. 6.6 *Correlation and regression equation of mean head circumference values in 13,740 Nigerian fetuses in Jos plotted against gestational age in weeks.*

When other fetal anthropometric parameters like biparietal diameter, occipitofrontal diameter, abdominal circumference, femur length and weight are plotted against head circumference certain hidden relationships can be forced out. For example, Fig. 6.7 shows the relationship of head circumference with biparietal diameter. From the graph, it can be seen that there is a positive linear correlation between biparietal diameter and head circumference with a correlation of determination of $R^2 = 0.9997$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the linear regression equation $y = 0.2792x – 0.8656$ where y is the biparietal diameter in millimeters and x is the head circumference in millimeters. Fig. 6.8 shows relationship of head circumference with occipitofrontal diameter (OFD) which has regression equation of y = 0.347 + 0.0528; $R^2 = 1$; P<0.0001. Other relationships can be calculated outside the skull. Fig. 6.9 shows relationship of head circumference with abdominal circumference. From the graph, it can be seen that there is a positive linear correlation between abdominal circumference and head circumference with a correlation of determination of $R^2 = 0.994$ (P < 0.0001) in Nigerian fetuses in Jos. The relationship is best described by the linear regression equation y = 1.0644x – 29.032 where y is the abdominal circumference in millimeters and x is the head circumference in millimeters.

Fig. 6.10 shows relationship between femur length and head circumference. There is a positive power correlation between femur length and head circumference with a correlation of determination of $R^2 = 0.9962$ (P < 0.0001) in Nigerian fetuses in Jos. The relationship is best described by the power regression equation $y = 0.046x^{1.2897}$ where y is the femur length in millimeters and x is the head circumference in millimeters. Fig. 6.11 shows the relationship between fetal weight which is strongly correlated with fetal nutrition and head circumference. The relationship is best described by the exponential regression equation $y = 57.144e^{0.012x}$ where y is the fetal weight in grams and x is the head circumference in millimeters.

Centile values for 5^{th}, 50^{th} and 95^{th} are plotted as shown in Fig. 6.12. In Fig. 6.13, the 5^{th}, 50^{th} and 95^{th} centile values of head circumference measurement are smoothened into a growth chart which can be utilized to determine growth and of course brain size development, strongly related to intelligence and wellness, using head circumference. Fig.6. 14 is a graphical display showing the growth rate of the measured fetal head circumference with a quadratic polynomial mathematical model predictive formula $y = 0.0008x^2 – 0.0095x + 2.1811$ ($R^2 = 0.721$; p<0.0001); where y is the fetal head circumference growth rate in millimeters and x is the gestational age in weeks. It is clear from this graph that growth rate is much higher in the early stages of development than the late ones which precede term.

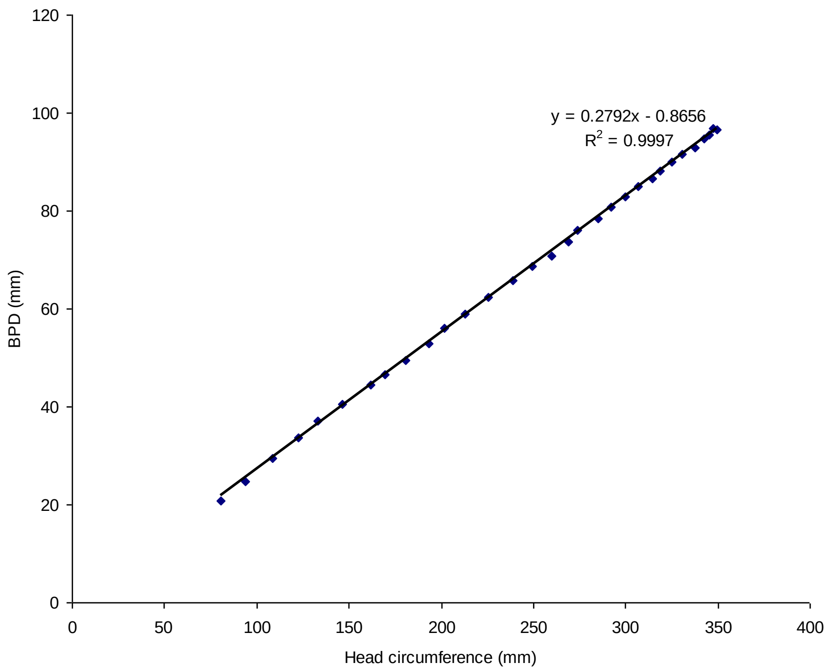

Fig. 6.7 *Correlation and regression equation of mean head circumference values in 13,740 Nigerian fetuses in Jos plotted against biparietal diameter.*

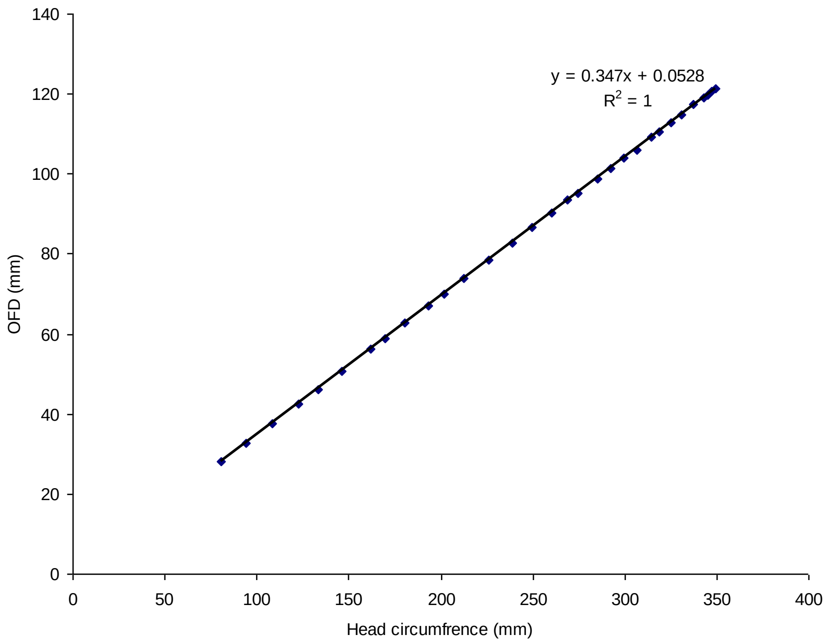

Fig. 6.8 *Correlation and regression equation of mean head circumference values in 13,740 Nigerian fetuses in Jos plotted against occipitofrontal diameter.*

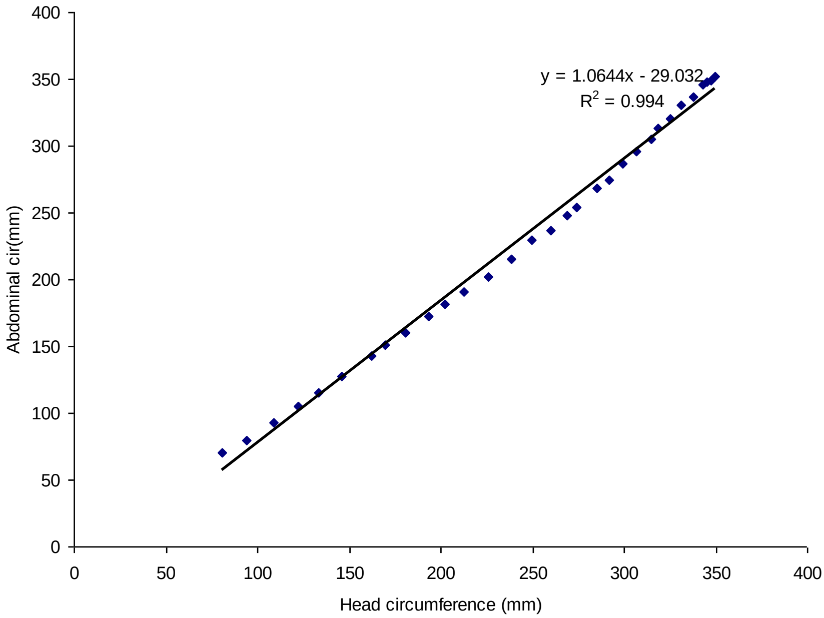

Fig. 6.9 *Correlation and regression equation of mean head circumference values in 13,740 Nigerian fetuses in Jos plotted against abdominal circumference.*

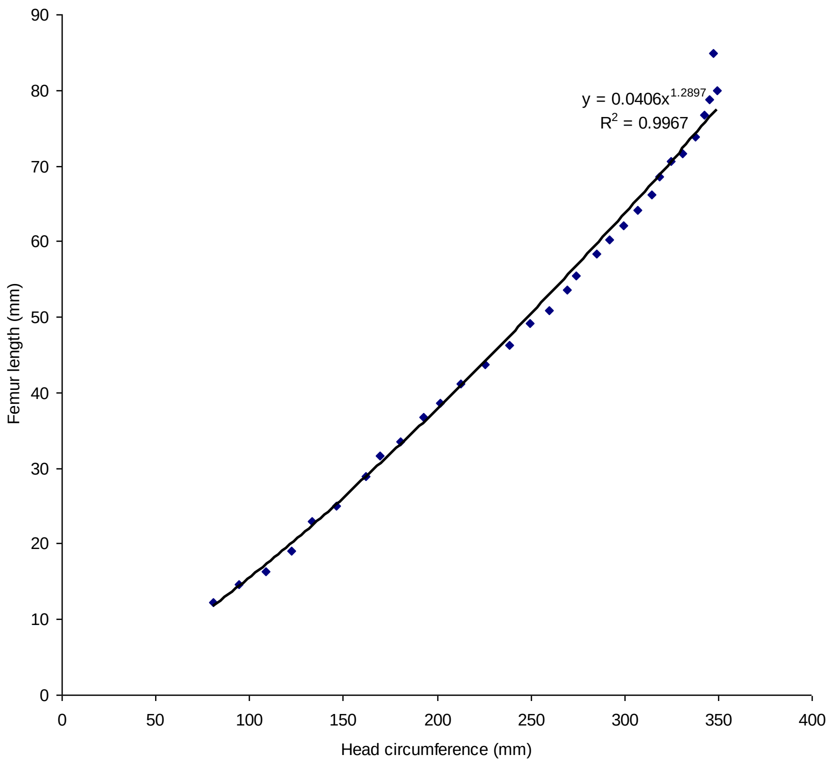

Fig. 6.10 *Correlation and regression equation of mean head circumference values in 13,740 Nigerian fetuses in Jos plotted against femur length.*

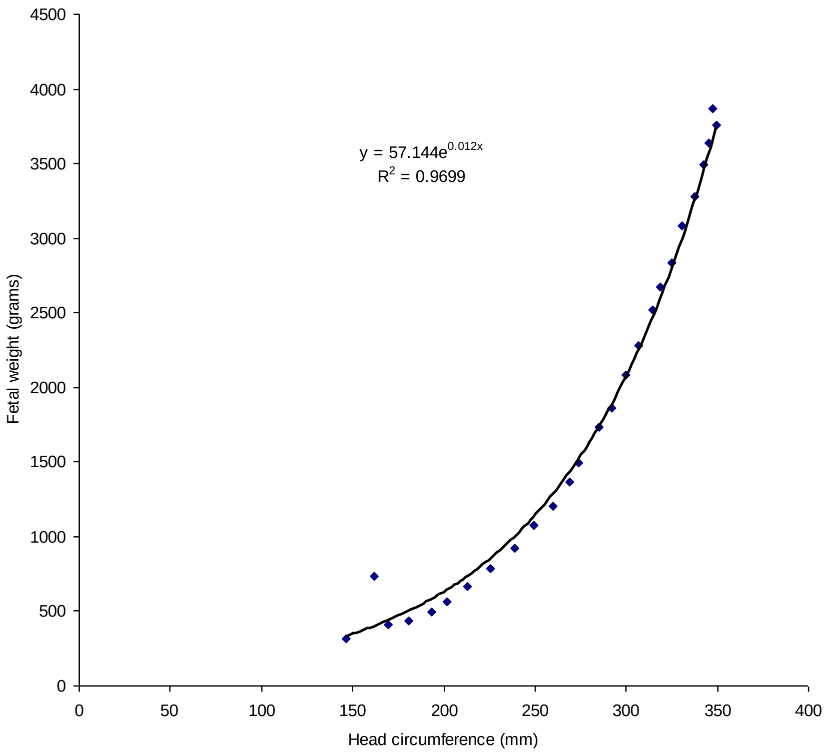

Fig. 6.11 *Correlation and regression equation of mean head circumference values in 13,740 Nigerian fetuses in Jos plotted against fetal weight.*

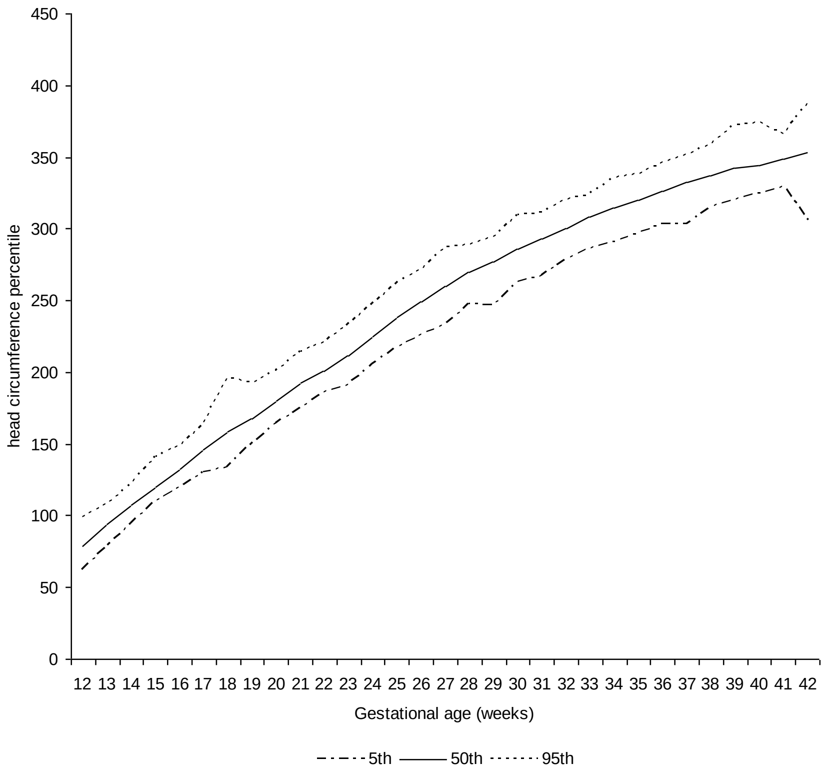

Fig. 6.12 *Fifth, 50th and 97th centiles for head circumference in 13,740 fetuses at different gestational ages from 12 to 42 weeks.*

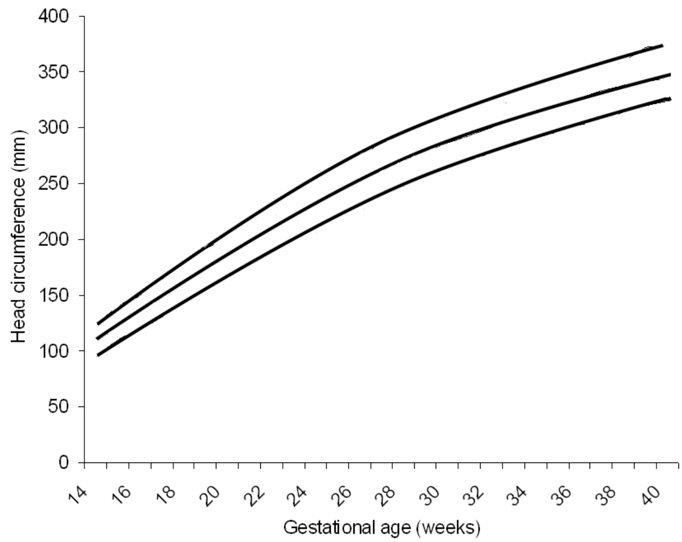

Fig. 6.13 *Curves created from 3rd, 50th and 97th fetal head circumference centiles.*

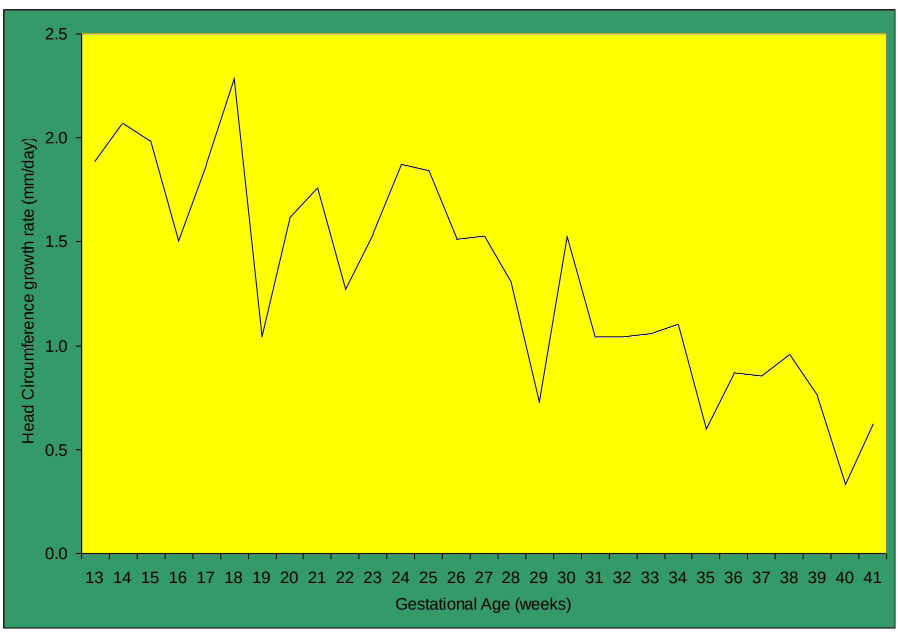

Fig. 6.14 *Growth velocity pattern of head circumference in 13,740 Nigerian fetuses in Jos.*

Biometrics of Fetal Biparietal Diameter

The fetal biparietal diameter measurements were classified into thirty one groups (Tab. 6.5). The group with the highest number of observations was from 34 to 34 + 6 while 42 to 42+6 group had the lowest number of observations. The measurements varied more at 18 to 18+6 group. The standard error of mean of BPD measurements is relatively small suggesting that the sample mean is very close to the population mean. For example, at 13 weeks gestation, the mean fetal biparietal diameter was 94.1mm while the standard error of mean was 0.5. This means that the difference between the mean biparietal diameters of the sample of fetuses at 13 weeks is just 0.5mm different from that of the population of fetuses at 13 weeks gestation.

The geometric means (Tab. 6.6) of all sets of measurements from 12 – 42 weeks are less than their arithmetic means but greater than their harmonic means indicating that all the values of fetal biparietal diameter measurements were not identical. Tab. 6.7 gives the centile values of fetal biparietal diameter measurements. This table gives the 3rd, 5th, 10th, 50th, 90th, 95th, and 97th centile values for fetal biparietal diameter measured at different gestational age ranging from 12 – 42 weeks. For example, it can be seen from the table that the 10th percentile of biparietal diameter at 20 to 20 + 6 weeks gestation is 48 millimeters. This means that 10% of the fetuses at 20 to 20 + 6 had a mean biparietal diameter less than 48 millimeters, while 90% had a mean biparietal diameter greater than 48 millimeters. Similarly, the 97th percentile of biparietal diameter at 36 to 36 + 6 is 94 millimeters. Hence 97% of fetuses at 36 to 36 + 6 had a mean biparietal diameter less than 94 millimeters while 3% had a mean biparietal diameter greater than 94 millimeters.

The standard score or z-score of biparietal diameter measurements in 13,740 fetuses ranging from 12 – 42 weeks of gestation is shown in Tab. 6.8. The z-score enables us to look at biparietal diameter measurements in each gestational age and see how they compare on the same standard; taking into account the mean and standard deviation of each gestational age. For example, biparietal diameter measurements at 15 weeks are 0.00133 standard deviations from the mean while measurements at 30 weeks are – 0.0407 standard deviations from the mean. Again, from the above z-score table, it can be seen that the biparietal diameter measurements at 38 weeks gestation are – 0.00499 standard deviations from the mean.

When biparietal diameter data of 13,740 fetuses was subjected to skewness analysis at different gestational age ranging from 12 – 42 weeks (Fig. 6.15), it can be seen that the distribution of biparietal diameter measurements has a longer “tail” to the left of the central maximum than to the right or is skewed to the left throughout pregnancy except at 14, 15, 18, 19, 20, 21 and 39 weeks where the distribution has a longer “tail” to the right of the central maximum than to the left or is skewed to the right.

When the biparietal diameter data was subjected to kurtosis analysis (Fig. 6.16), the analysis was found to be leptokurtic at 15, 18, 19, 22 and 29 weeks of gestation while at 12, 13, 16,17, 20, 21, 23, 24, 25, 26, 27, 28, 20, 31, 32,34, 35, 36, 39, 40, 41 and 42 weeks of gestation, the kurtosis was mesokurtic. The coefficient of dispersion of biparietal diameter data of 13,740 fetuses at different gestational age shows a decrease in value as gestational age advances except at 18, 20, 30 and 42 weeks where it peaks. At 25 weeks, it falls to zero before rising again (Fig. 6.17). The biparietal diameter scattergram in Fig. 6.18 shows that there are very few bad data points or outliers in the biparietal diameter measurements of 13,740 fetuses. The outliers are more from 26 – 42 weeks of gestation. This shows the pattern of growth recognized for neural tissue which suggests growth of brain.

Tab. 6.5 *Frequency Distribution Table of Fetal Biparietal Diameter Measurements Showing the Arithmetic mean, Standard Deviation and Standard Error of Mean from 12 – 42 weeks gestation.*

GA (wks, days)	Fetuses (n)	BPD(mm)	SD	SEM
12 to 12+6	49	20.9	2.0	0.2
13 to 13+6	384	24.8	2.1	0.1
14 to 14+6	371	29.4	2.0	0.1
15 to 15+6	351	33.6	3.0	0.2
16 to 16+6	505	37.1	1.7	0.0
17 to 17+6	427	40.5	2.0	0.0
18 to 18+6	446	44.4	5.1	0.2
19 to 19+6	282	46.6	2.8	0.2
20 to 20+6	553	49.4	2.2	0.0
21 to 21+6	400	52.9	1.7	0.0
22 to 22+6	398	56.1	2.7	0.1
23 to 23+6	478	59.0	1.8	0.0
24 to 24+6	520	62.3	2.3	0.1
25 to 25+6	388	65.8	2.2	0.1
26 to 26+6	511	68.6	2.3	0.1
27 to 27+6	432	70.8	2.2	0.1
28 to 28+6	548	73.6	3.6	0.2
29 to 29+6	484	76.0	3.3	0.2
30 to 30+6	625	78.4	3.5	0.1
31 to 31+6	523	80.7	2.5	0.1
32 to 32+6	583	82.8	2.7	0.1
33 to 33+6	516	85.0	2.0	0.0
34 to 34+6	744	86.6	3.4	0.1
35 to 35+6	739	88.2	2.7	0.0
36 to 36+6	599	90.0	2.8	0.1
37 to 37+6	532	91.5	2.2	0.0
38 to 38+6	481	93.0	2.5	0.1
39 to 39+6	525	94.7	2.6	0.1
40 to 40+6	252	95.6	2.3	0.2
41 to 41+6	72	96.5	2.3	0.3
42 to 42+6	22	96.9	2.7	0.6
Total	13,740			

Tab. 6.6 *Frequency distribution table of fetal head circumference measurements showing arithmetic mean, geometric mean and harmonic mean from 12 – 42 weeks gestation.*

GA (week, days)	Number of fetuses (n)	Arithmetic mean (mm)	Geometric mean (mm)	Harmonic mean(mm)
12 to 12+6	49	20.89796	20.8133	20.73384
13 to 13+6	384	24.79427	24.6967	24.58586
14 to 14+6	371	29.3504	29.27582	29.19156
15 to 15+6	351	33.60399	33.50901	33.43465
16 to 16+6	505	37.05941	37.01759	36.9743
17 to 17+6	427	40.52693	40.47596	40.42076
18 to 18+6	446	44.40359	44.19772	44.04385
19 to 19+6	282	46.61702	46.55173	46.4993
20 to 20+6	553	49.37613	49.33103	49.28833
21 to 21+6	400	52.9325	52.90432	52.87666
22 to 22+6	398	56.11055	56.05551	56.00847
23 to 23+6	478	59.03138	59.00269	58.97365
24 to 24+6	520	62.31538	62.27158	62.22575
25 to 25+6	388	65.84021	65.80398	65.76709
26 to 26+6	511	68.61644	68.57739	68.53812
27 to 27+6	432	70.84259	70.80765	70.77187
28 to 28+6	548	73.64051	73.49528	73.23101
29 to 29+6	484	75.98967	75.89696	75.77091
30 to 30+6	625	78.4288	78.34548	78.25781
31 to 31+6	523	80.73422	80.69387	80.65249
32 to 32+6	583	82.78902	82.73907	82.68323
33 to 33+6	516	84.98062	84.9576	84.93434
34 to 34+6	744	86.55645	86.48273	86.39934
35 to 35+6	739	88.15833	88.11768	88.07617
36 to 36+6	599	90.00835	89.96366	89.91594
37 to 37+6	532	91.49436	91.46841	91.44218
38 to 38+6	481	92.98753	92.95243	92.91693
39 to 39+6	525	94.74857	94.71294	94.67731
40 to 40+6	252	95.56349	95.53491	95.5063
41 to 41+6	72	96.45834	96.43224	96.40612
42 to 42+6	22	96.90909	96.87257	96.83514
Total	13740			

Tab. 6.7 *Fetal biparietal diameter centiles from 12 – 42 weeks.*

	Biparietal diameter (mm)						
GA (wks, days)	**3rd**	**5th**	**10th**	**50th**	**90th**	**95th**	**97th**
12 to 12+6	19.0	19.0	19.0	20.0	24.0	25.5	26.0
13 to 13+6	20.0	22.0	22.5	25.0	27.0	27.0	27.0
14 to 14+6	26.2	27.0	28.0	29.0	31.0	31.0	32.0
15 to 15+6	31.0	31.0	32.0	34.0	35.0	35.0	35.4
16 to 16+6	33.0	34.0	35.0	37.0	39.0	39.0	39.0
17 to 17+6	37.0	38.0	38.8	41.0	42.0	42.0	43.2
18 to 18+6	41.0	41.0	42.0	44.0	45.0	46.0	47.0
19 to 19+6	44.0	44.2	45.0	46.0	47.0	49.0	50.0
20 to 20+6	46.0	47.0	48.0	49.0	51.0	52.0	53.4
21 to 21+6	49.0	50.0	51.0	53.0	54.0	55.0	56.0
22 to 22+6	53.0	53.0	54.0	56.0	57.0	59.0	60.0
23 to 23+6	55.0	56.0	57.0	59.0	61.0	61.0	62.0
24 to 24+6	56.6	58.0	60.0	63.0	64.0	65.0	67.0
25 to 25+6	62.0	63.0	64.0	66.0	68.0	69.0	70.0
26 to 26+6	63.0	64.0	66.0	69.0	70.0	72.0	74.0
27 to 27+6	64.0	66.0	68.0	71.0	72.7	74.0	75.0
28 to 28+6	69.0	71.0	72.0	74.0	75.1	77.0	78.0
29 to 29+6	70.7	73.0	74.0	76.0	78.0	78.8	79.0
30 to 30+6	71.0	72.0	74.0	79.0	81.0	84.0	85.0
31 to 31+6	74.7	76.0	78.0	81.0	83.0	84.0	84.3
32 to 32+6	77.0	78.0	80.0	83.0	85.0	87.0	87.0
33 to 33+6	80.0	82.0	82.0	85.0	87.0	88.0	88.0
34 to 34+6	80.4	82.0	83.5	87.0	89.0	91.0	92.0
35 to 35+6	82.0	83.0	85.0	89.0	91.0	92.0	93.0
36 to 36+6	84.0	85.0	87.0	90.0	92.0	93.0	94.0
37 to 37+6	87.0	87.0	89.0	92.0	94.0	94.0	95.0
38 to 38+6	88.0	89.0	90.0	93.0	96.0	97.0	98.0
39 to 39+6	90.0	91.0	92.0	94.0	98.0	99.0	99.0
40 to 40+6	91.0	91.0	93.0	95.0	98.7	100.0	100.0
41 to 41+6	91.2	92.0	93.0	96.0	100.0	101.0	101.0
42 to 42+6	91.0	91.0	91.0	98.0	99.0	99.0	99.0

Tab. 6.8 *Standard score (z-score) of biparietal diameter measurements in 13,740 Nigerian fetuses in Jos ranging from 12 – 42 weeks gestation.*

Gestational age (weeks)	Fetuses (n)	Mean z-score
12 to 12+6	49	-2.71565
13 to 13+6	384	-2.73E-03
14 to 14+6	371	-2.48E-02
15 to 15+6	351	1.33E-03
16 to 16+6	505	-2.39E-02
17 to 17+6	427	3.47E-03
18 to 18+6	446	7.03E-04
19 to 19+6	282	6.08E-03
20 to 20+6	553	-1.08E-02
21 to 21+6	400	1.91E-02
22 to 22+6	398	3.91E-03
23 to 23+6	478	1.74E-02
24 to 24+6	520	6.69E-03
25 to 25+6	388	1.83E-02
26 to 26+6	511	7.15E-03
27 to 27+6	432	1.94E-02
28 to 28+6	548	1.13E-02
29 to 29+6	484	-3.13E-03
30 to 30+6	625	-4.89E-02
31 to 31+6	523	1.52E-03
32 to 32+6	583	-4.07E-03
33 to 33+6	516	-9.69E-03
34 to 34+6	744	-1.41E-02
35 to 35+6	739	-1.54E-02
36 to 36+6	599	2.98E-03
37 to 37+6	532	-2.56E-03
38 to 38+6	481	-4.99E-03
39 to 39+6	525	1.87E-02
40 to 40+6	252	-1.59E-02
41 to 41+6	72	-1.81E-02
42 to 42+6	22	3.37E-03
Total	13740	

In Fig. 6.19, mean biparietal diameter is plotted against gestational age with error bars showing standard deviation. Arithmetic mean and standard deviation go together like star and satellite. With the mean, we have some idea of the kind of numbers it represents, but the whole story is still a mystery. To clear up the mystery of the hidden numbers that made up a mean, the standard deviation is necessary. For example, the mean ± 1 standard deviation will include about 2 out of 3 numbers in the group while the mean ± 2 standard deviations will include about 95 out of 100 numbers in the group and the mean ± 3 standard deviations will include 997 numbers out of 1,000. Mathematical modeling of fetal biparietal diameter data demonstrated that the best-fitted regression model to describe the relationship between biparietal diameter and gestational age is as shown in Fig. 6.20. There is a positive polynomial correlation between gestational age and biparietal diameter with a correlation of determination of $R^2 = 0.9996$ ($P < 0.0001$) in Nigerian fetuses in Jos.

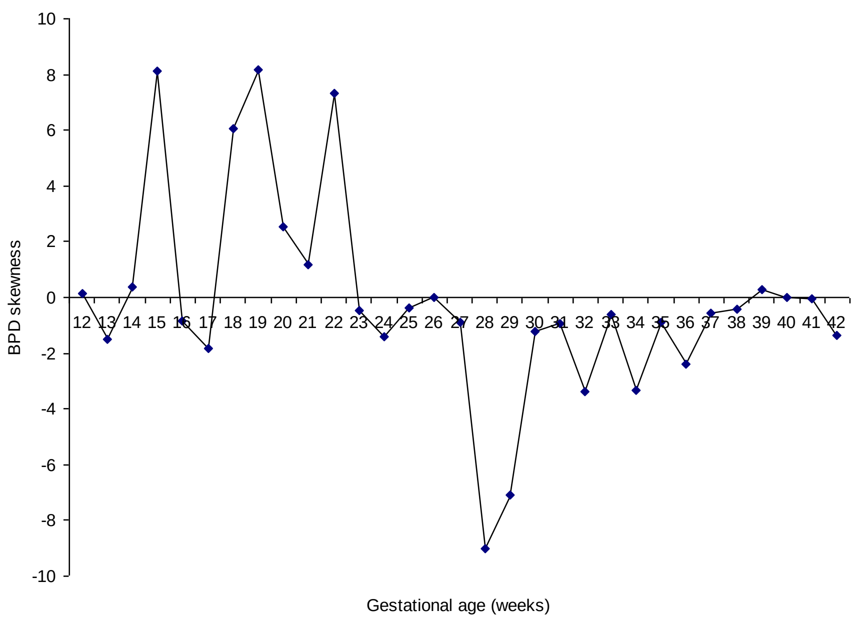

Fig. 6.15 *Biparietal diameter data of 13,740 fetuses subjected to Skewness analysis at different gestational age ranging from 12 – 42 weeks.*

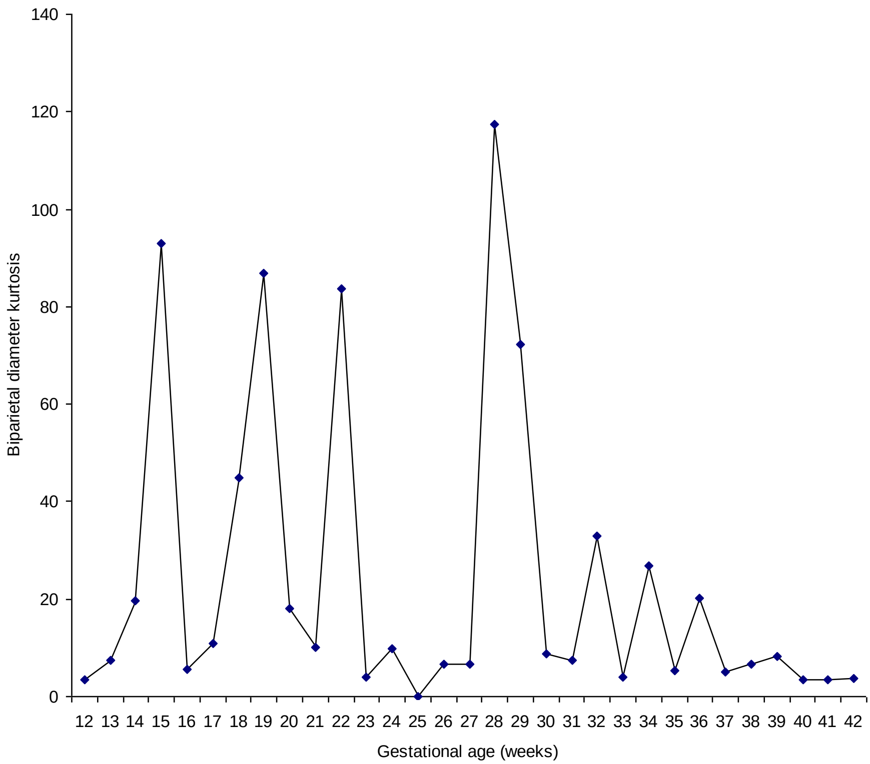

Fig. 6.16 *Biparietal diameter data of 13,740 fetuses subjected to kurtosis analysis at different gestational age ranging from 12 – 42 weeks.*

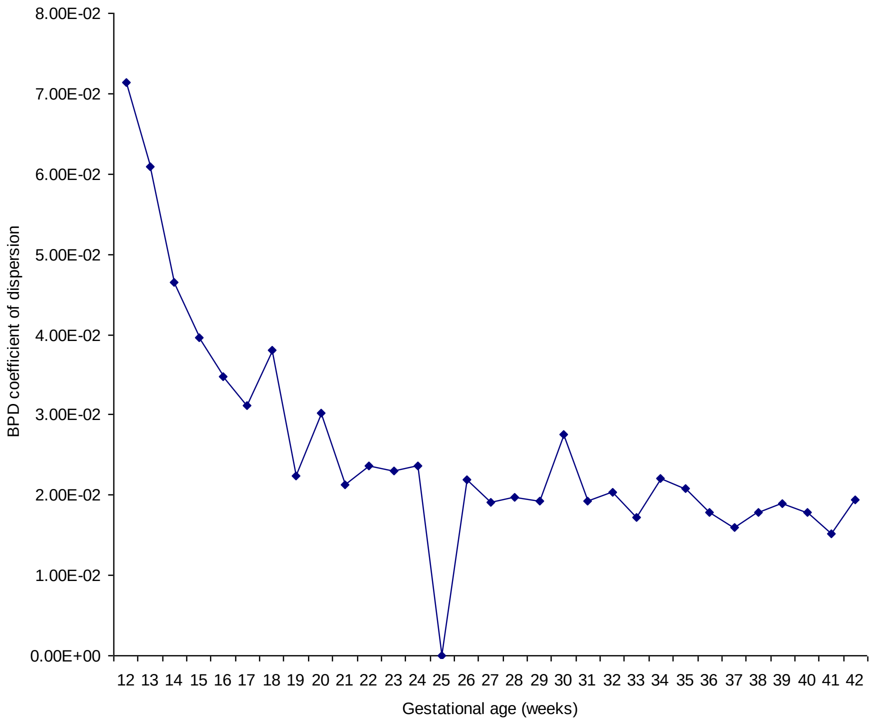

Fig. 6.17 *Biparietal diameter coefficient of dispersion in 13,740 fetuses of gestational ages between 12 to 42 weeks.*

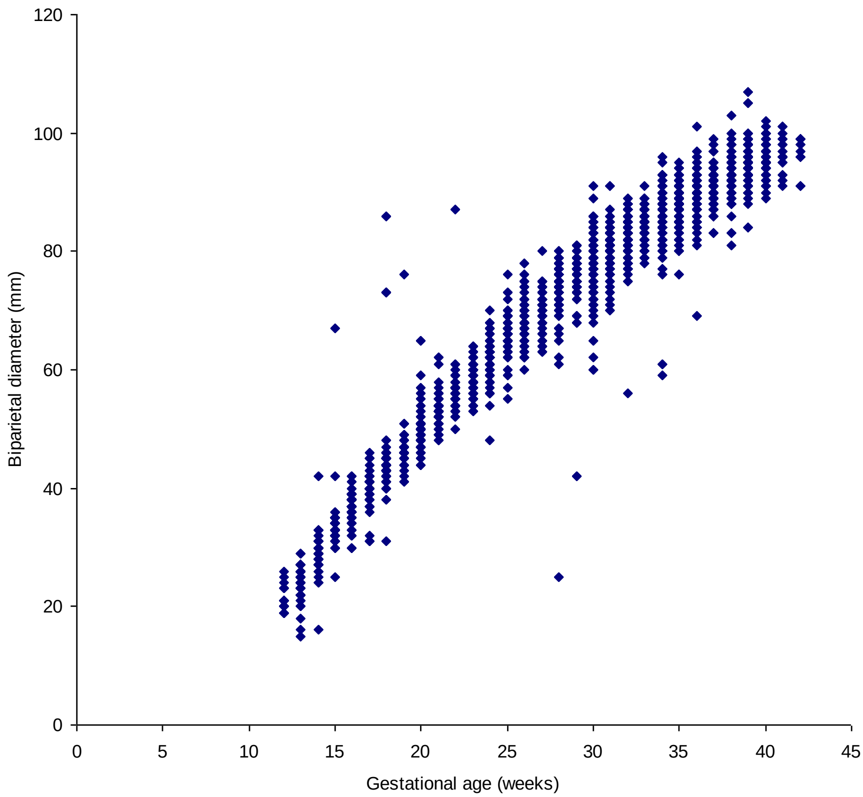

Fig. 6.18 *Scattergram of 13,740 fetal biparietal diameter measurements from 12 – 42 weeks gestation.*

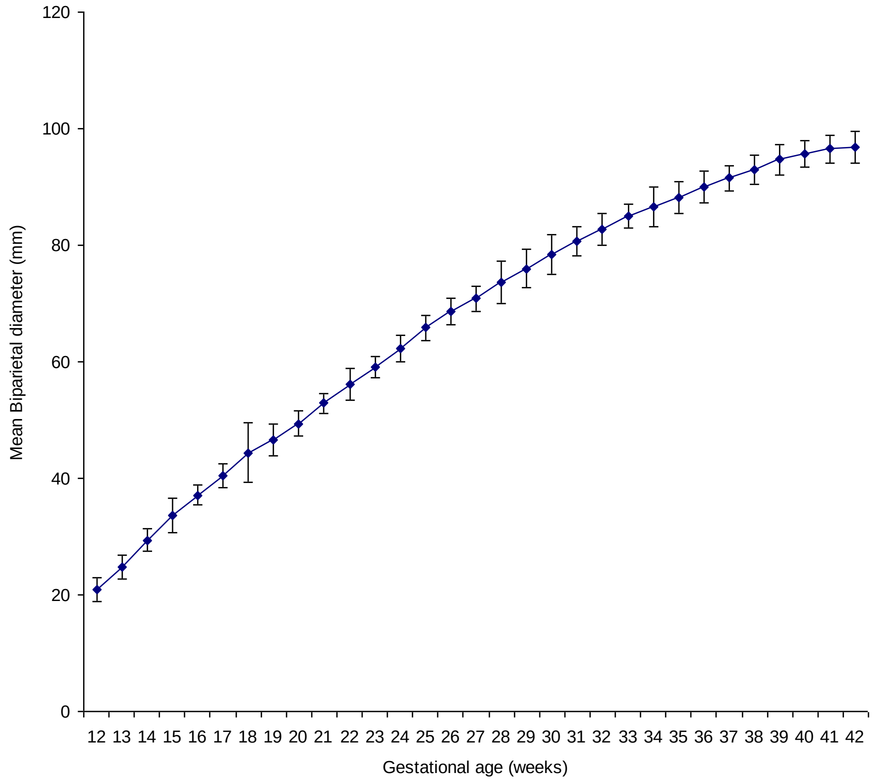

Fig. 6.19 *Mean fetal biparietal diameter values in 13,740 fetuses of women at different gestational ages between 12 – 42 weeks. The vertical bars show the values of ±SD.*

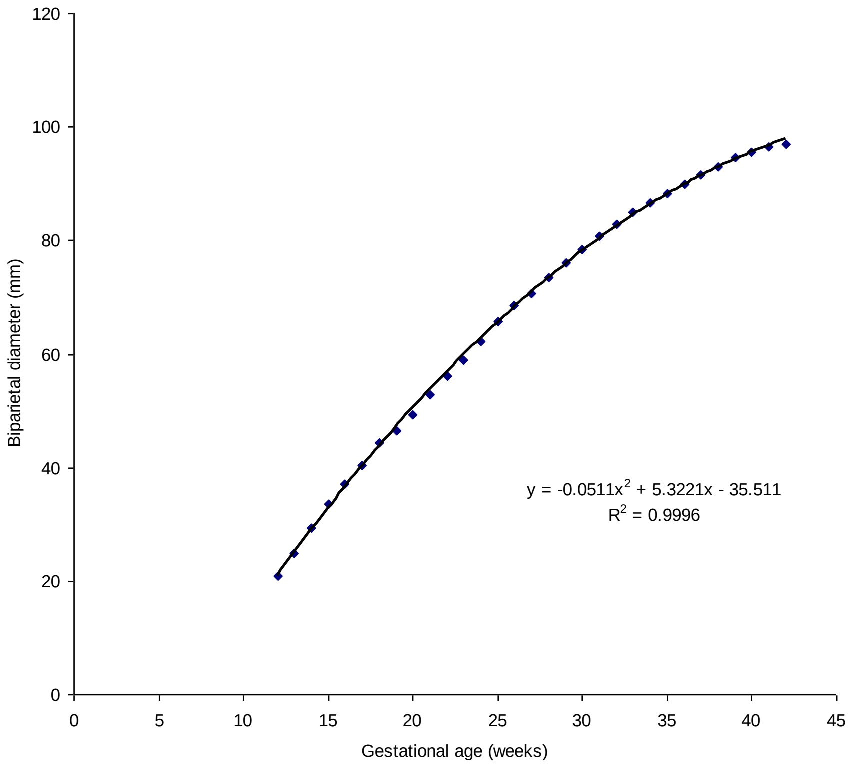

Fig. 6.20 *Correlation and regression equation of mean biparietal diameter values in 13,740 Nigerian fetuses in Jos plotted against gestational age in weeks.*

The relationship is best described by the second order polynomial regression equation $y = -0.0511x^2 + 5.3221x - 35.511$ where y is the biparietal diameter in millimeters and x is the gestational age in weeks. This means that biparietal diameter could predict the gestational age of fetuses by 99.99 percent ($R^2 = 0.9999$) in 13,740 fetuses in this study. When other fetal anthropometric parameters like head circumference, occipitofrontal diameter, abdominal circumference, femur length and weight are plotted against biparietal diameter certain hidden relationships can be forced out. For example, Fig. 6.21 shows the relationship between biparietal diameter and head circumference. From the graph, it can be seen that there is a positive linear correlation between biparietal diameter and head circumference with a correlation of determination of $R^2 = 0.9997$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the linear regression equation $y = 3.5811x + 3.1775$ where x is the biparietal diameter in millimeters and y is the head circumference in millimeters.

Fig. 6.22 shows the relationship of biparietal diameter with occipitofrontal diameter. From the graph, it can be seen that there is a positive linear correlation between occipitofrontal diameter and biparietal diameter with a correlation of determination of $R^2 = 0.9997$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the linear regression equation $y = 1.2425x + 1.1552$ where y is the occipitofrontal diameter in millimeters and x is biparietal diameter in millimeters.

Fig. 6.23 shows the relationship of biparietal diameter with abdominal circumference. From the graph, it can be seen that there is a positive linear correlation between abdominal circumference and biparietal diameter with a correlation of determination of $R^2 = 0.9994$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by second order polynomial regression equation $y = 0.0144x^2 + 2.0241x + 21.816$ where y is the abdominal circumference in millimeters and x is the biparietal diameter in millimeters.

Fig. 6.24 shows relationship between femur length and biparietal diameter. There is a positive power correlation between femur length and biparietal diameter with a correlation of determination of $r^2 = 0.9986$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the fourth order polynomial regression equation $y = 5E\text{-}06x^4 – 0.0011x^3 + 0.0855x^2 – 2.0951x + 27.664$ where y is the femur length in millimeters and x is the biparietal diameter in millimeters. Fig. 6.25 shows the relationship between fetal weight which is strongly correlated with fetal nutrition and biparietal diameter. There is a positive exponential correlation between fetal weight and biparietal diameter with a correlation of determination of

$r^2 = 0.9988$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the exponential regression equation $y = 45.141e^{0.0461x}$ where y is the fetal weight in grams and x is the biparietal diameter in millimeters.

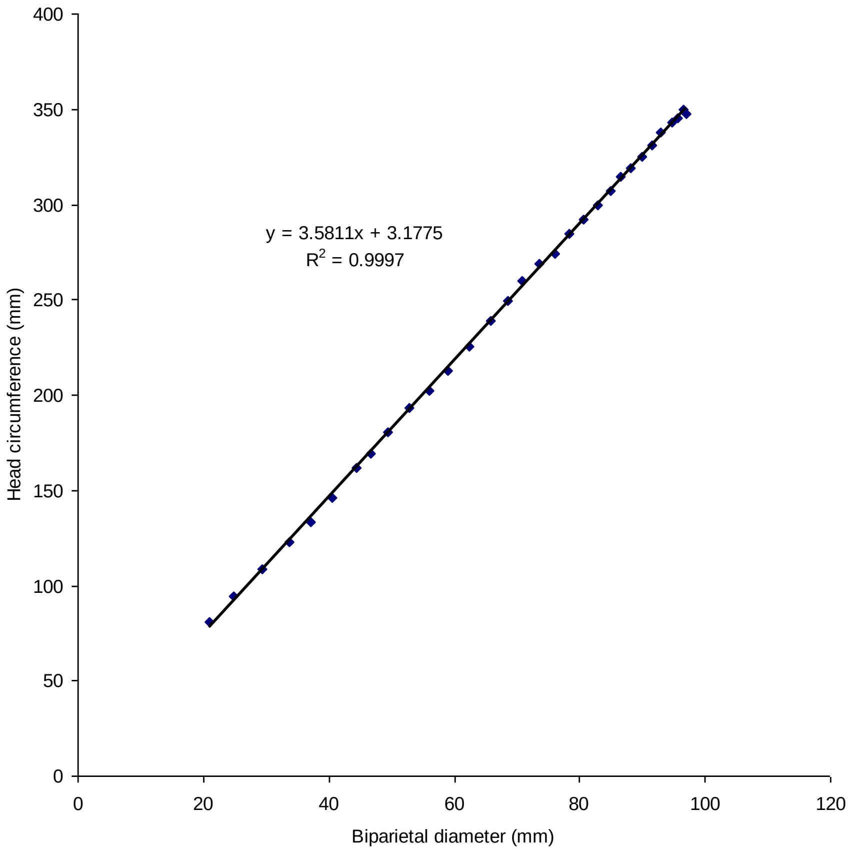

Fig. 6.21 *Correlation and regression equation of mean head circumference values in 13,740 Nigerian fetuses in Jos plotted against biparietal diameter.*

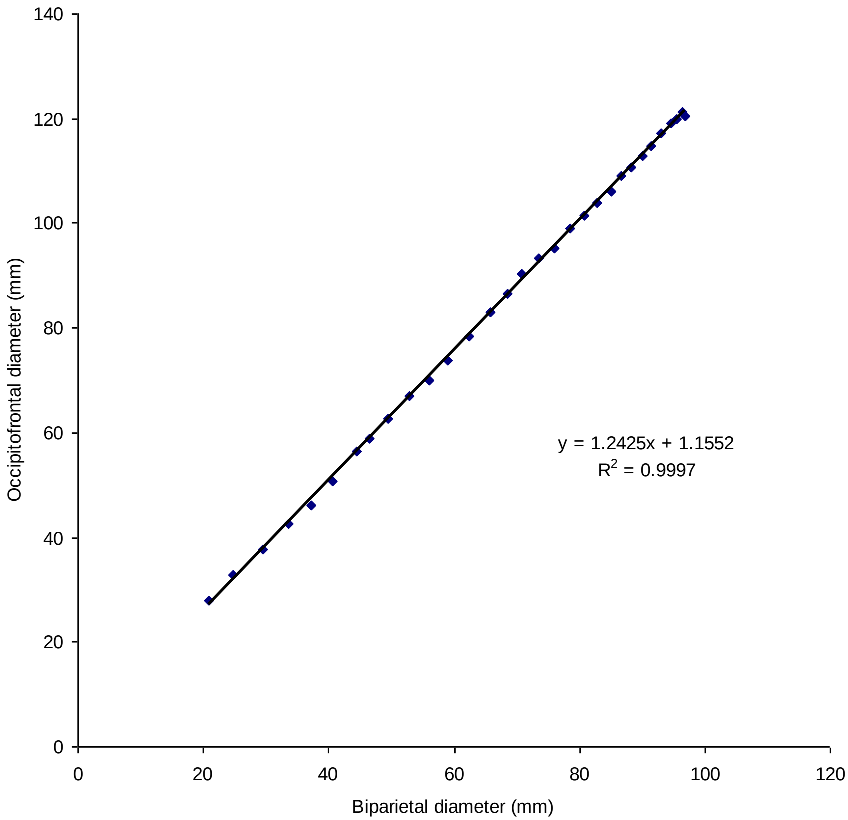

Fig. 6.22 *Correlation and regression equation of mean biparietal diameter values in 13,740 Nigerian fetuses in Jos plotted against occipitofrontal diameter.*

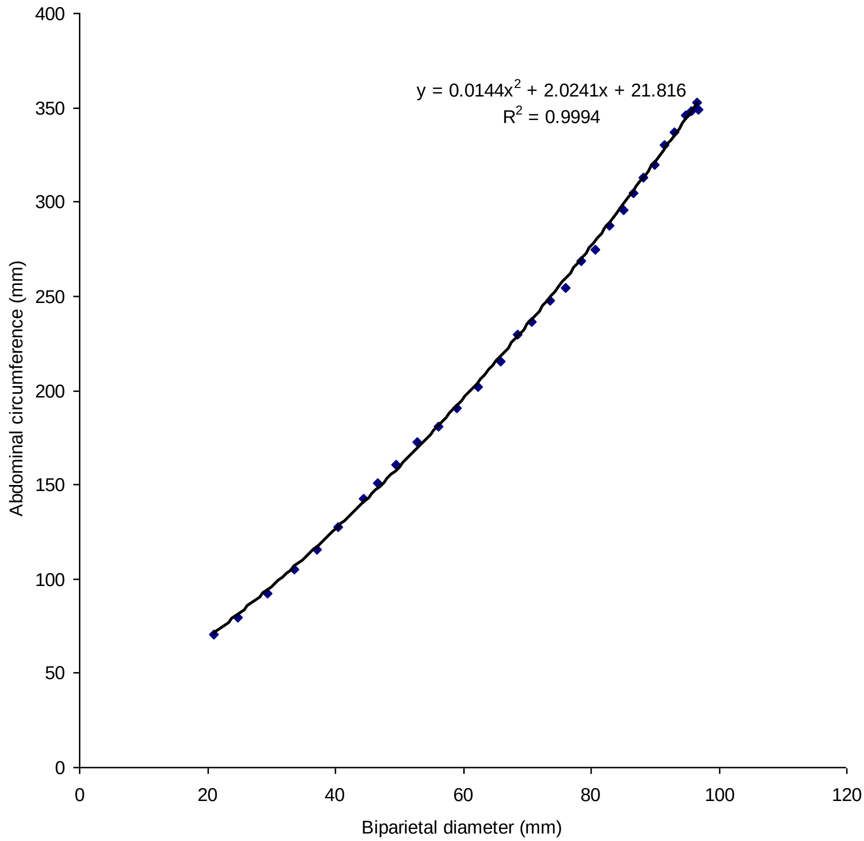

Fig. 6.23 *Correlation and regression equation of mean biparietal diameter values in 13,740 Nigerian fetuses in Jos plotted against abdominal circumference.*

Centile values for 5th, 50th and 95th are plotted as shown in Fig. 6.26. In Fig. 6.27, the 3rd, 50th and 97th of biparietal diameter are smoothened into a growth chart which can be utilized to determine growth and of course brain size development, which is strongly related to intelligence and wellness, using biparietal diameter. Fig. 6.28 is a graphical display showing the growth rate of the measured fetal biparietal diameter. It is clear from this graph that growth rate is much higher in the early stages of development than the late ones which precede term.

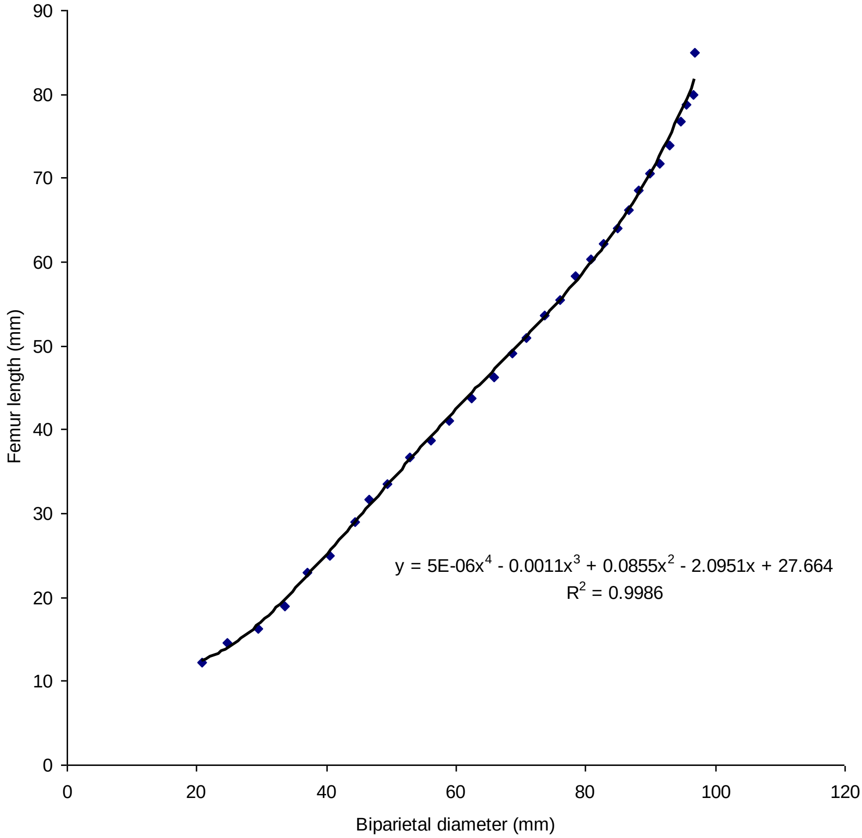

Fig. 6.24 *Correlation and regression equation of mean biparietal diameter values in 13,740 Nigerian fetuses in Jos plotted against femur length.*

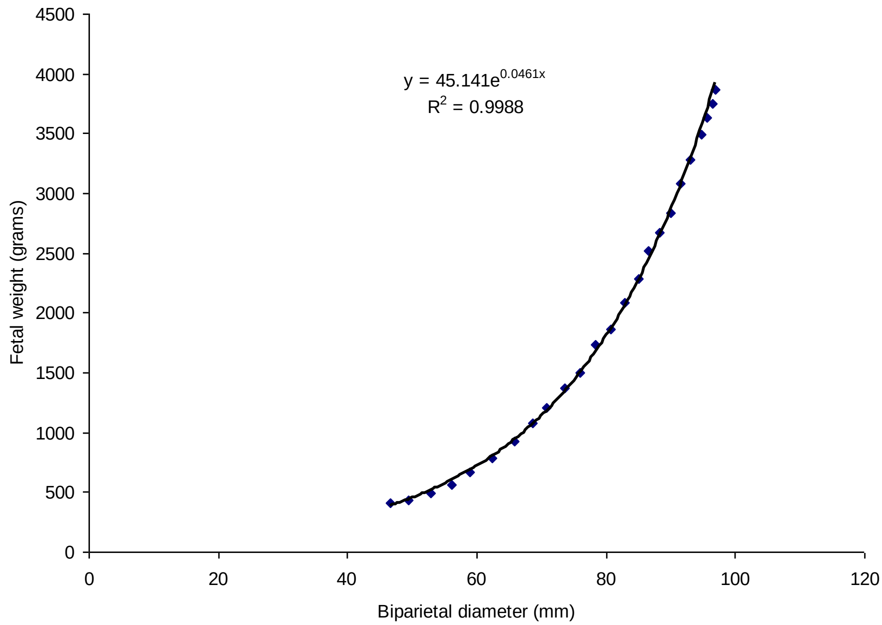

Fig. 6.25 *Correlation and regression equation of mean biparietal diameter values in 13,740 Nigerian fetuses in Jos plotted against fetal weight.*

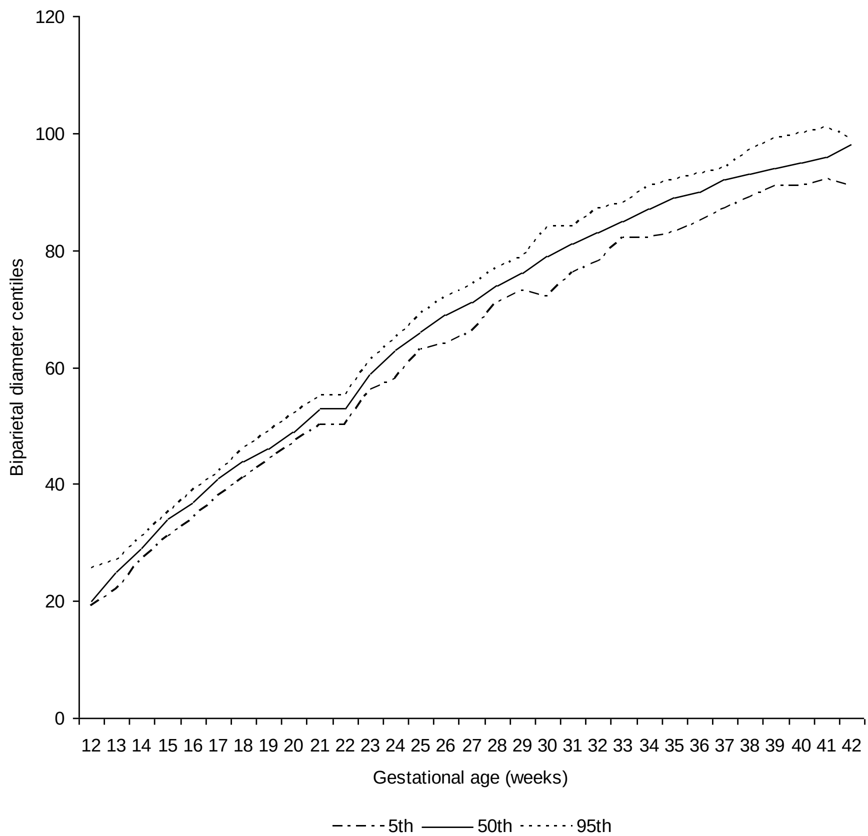

Fig. 6.26 *Fifth, 50th and 97th centiles for biparietal diameter in 13,740 fetuses at different gestational ages from 12 to 42 weeks.*

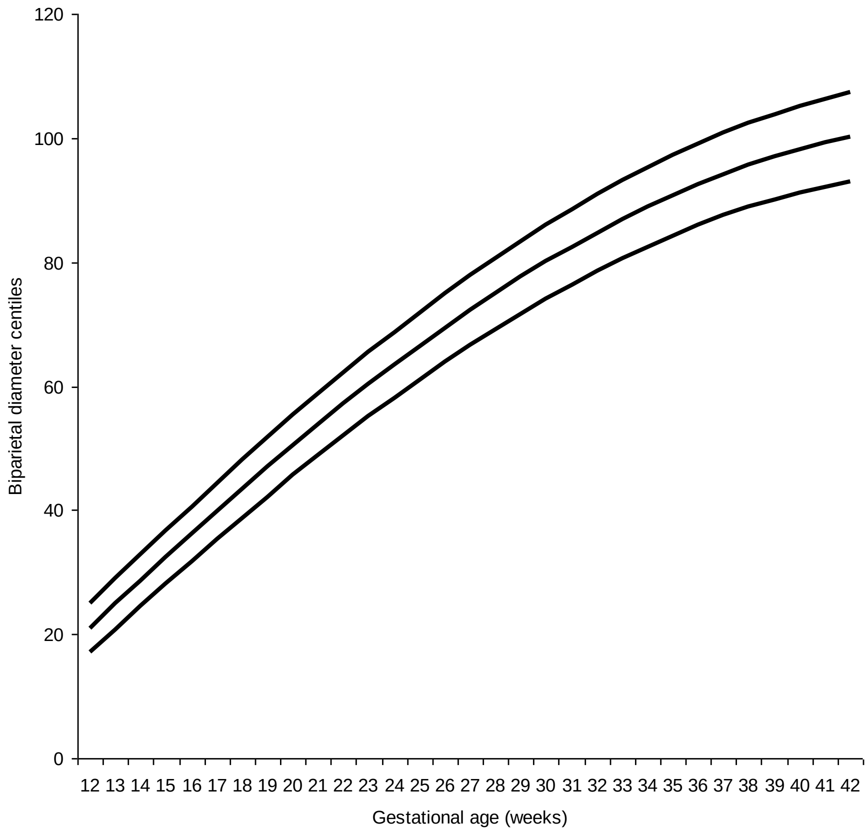

Fig. 6.27 *Curves created from 3rd, 50th and 97th fetal biparietal diameter centiles.*

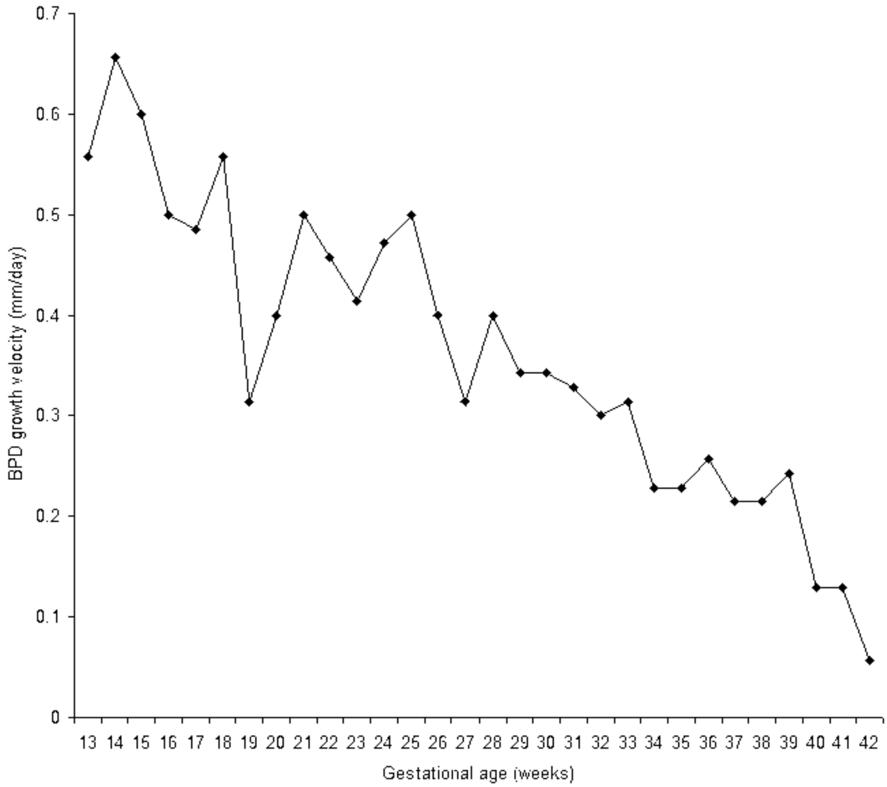

Fig. 6.28 *Growth velocity pattern of biparietal diameter in 13,740 Nigerian fetuses in Jos ranging from 12 – 42 weeks.*

Biometrics of Fetal Occipitofrontal Diameter

The mean fetal occipitofrontal diameter values at each week of gestation from 12 – 42 are as shown in Tab. 6.9. This table gives the mean values of fetal occipitofrontal diameter measurements for each gestational age in weeks from 12 – 42 weeks together with their corresponding standard deviations and standard errors of mean. The highest mean value was obtained at 42 weeks while the least mean value was gotten at 12 weeks. The range of variability was 3.7 and 5.3 for the minimum and maximum values respectively. With the arithmetic mean, one has some idea of the kind of numbers it represents, but the whole story is still a mystery. To clear up the mystery of the hidden numbers that made up a mean, the standard deviation is necessary. For example, the mean occipitofrontal diameter at 19 weeks is 58.9mm plus 5.3mm or 58.9mm minus 5.3mm. This means 2 out of 3 measurements of occipitofrontal diameter at 19 weeks, approximately 188 occipitofrontal diameter measurements in a class of 282, should be between 53.6mm and 64.2mm. Since the standard error of mean at 19 weeks is 0.3mm, it is telling us that the real mean occipitofrontal diameter of fetuses in Jos at 19 weeks is probably between 58.6mm and 59.2mm (58.9mm plus or minus 0.3mm). It can also be seen that the standard error of mean for each week of gestation from 12 – 42 is very small suggesting that the sample mean is very close to the population mean. For example, at 13 weeks gestation, the mean fetal occipitofrontal diameter was 94.1mm while the standard error of mean was 0.5. This means that the difference between the mean occipitofrontal diameters of the sample of fetuses at 13 weeks is just 0.5mm different from that of the population of fetuses at 13 weeks gestation. The geometric means (Tab. 6.10) of all sets of measurements from 12 – 42 weeks are less than their arithmetic means but greater than their harmonic means indicating that all the values of fetal occipitofrontal diameter measurements were not identical. Tab.6.11 gives the centile values of fetal occipitofrontal diameter measurements. This table gives the 3^{rd}, 5^{th}, 10^{th}, 50^{th}, 90^{th}, 95^{th}, and 97^{th} centile values for fetal occipitofrontal diameter measured at different gestational age ranging from 12 – 42 weeks. For example, it can be seen from the table that the 10^{th} percentile of occipitofrontal diameter at 20 to 20 + 6 weeks gestation is 59 millimeters.

Tab. 6.9 *Frequency distribution table of fetal occipitofrontal diameter measurements showing arithmetic mean, standard deviation and standard error of mean from 12 – 42 weeks gestation.*

GA (week, days)	Fetuses (n)	Mean OFD (mm)	SD	SEM
12 to 12+6	49	28	3.7	0.5
13 to 13+6	384	32.7	3.3	0.2
14 to 14+6	371	37.7	4.1	0.2
15 to 15+6	351	42.5	4.8	0.3
16 to 16+6	505	46.2	3.4	0.2
17 to 17+6	427	50.8	3.8	0.2
18 to 18+6	446	56.3	8.1	0.4
19 to 19+6	282	58.9	5.3	0.3
20 to 20+6	553	62.8	4.4	0.2
21 to 21+6	400	67.1	4.1	0.2
22 to 22+6	398	70.1	4	0.2
23 to 23+6	478	73.9	4.8	0.2
24 to 24+6	520	78.4	4.6	0.2
25 to 25+6	388	82.9	4.9	0.2
26 to 26+6	511	86.6	5.3	0.2
27 to 27+6	432	90.3	5.4	0.3
28 to 28+6	548	93.4	4.6	0.2
29 to 29+6	484	95.2	8.1	0.4
30 to 30+6	625	98.9	6	0.2
31 to 31+6	523	101.5	5.2	0.2
32 to 32+6	583	104	5.1	0.2
33 to 33+6	516	106	4.5	0.2
34 to 34+6	744	109.2	5.2	0.2
35 to 35+6	739	110.7	4.7	0.2
36 to 36+6	599	112.9	5.1	0.2
37 to 37+6	532	114.9	4.7	0.2
38 to 38+6	481	117.3	5.3	0.2
39 to 39+6	525	119	5	0.2
40 to 40+6	252	119.8	4.9	0.3
41 to 41+6	72	121.3	4.1	1.5
42 to 42+6	22	120.6	8.2	1.7
Total	13,740			

Tab. 6.10 *Frequency distribution table of fetal occipitofrontal diameter measurements showing arithmetic mean, geometric mean and harmonic mean from 12 – 42 weeks gestation.*

GA (week, days)	Number of fetuses (n)	Arithmetic mean (mm)	Geometric mean (mm)	Harmonic mean (mm)
12 to 12+6	49	28.02041	27.7769	27.52186
13 to 13+6	384	32.67969	32.49849	32.30374
14 to 14+6	371	37.72507	37.5314	37.35426
15 to 15+6	351	42.54986	42.33276	42.14695
16 to 16+6	505	46.16832	46.04197	45.91577
17 to 17+6	427	50.77986	50.63799	50.49517
18 to 18+6	446	56.33184	55.87227	55.49466
19 to 19+6	282	58.88298	58.66893	58.47072
20 to 20+6	553	62.78843	62.64119	62.50017
21 to 21+6	400	67.08	66.95792	66.83591
22 to 22+6	398	70.07789	69.969	69.86189
23 to 23+6	478	73.86192	73.70367	73.54012
24 to 24+6	520	78.375	78.24005	78.10592
25 to 25+6	388	82.89433	82.74525	82.58868
26 to 26+6	511	86.55968	86.39996	86.24117
27 to 27+6	432	90.25926	90.09711	89.93079
28 to 28+6	548	93.44526	93.32742	93.20554
29 to 29+6	484	95.21694	94.65898	93.60843
30 to 30+6	625	98.8752	98.68735	98.48719
31 to 31+6	523	101.4646	101.321	101.1645
32 to 32+6	583	104.0069	103.8739	103.7304
33 to 33+6	516	106.5562	106.456	106.3478
34 to 34+6	744	109.2218	109.0918	108.9546
35 to 35+6	739	110.7172	110.6159	110.5123
36 to 36+6	599	112.8781	112.7592	112.6352
37 to 37+6	532	114.9004	114.802	114.7024
38 to 38+6	481	117.2599	117.1476	117.0403
39 to 39+6	525	119.0152	118.9098	118.8046
40 to 40+6	252	119.8294	119.7336	119.6402
41 to 41+6	72	121.2639	121.1941	121.1232
42 to 42+6	22	120.6364	120.3676	120.0943
Total	13740			

Tab. 6.11 *Fetal occipitofrontal diameter centiles from 12 – 42 weeks.*

	Occipitofrontal diameter centiles (mm)						
Gestational age (weeks, days)	**3rd**	**5th**	**10th**	**50th**	**90th**	**95th**	**97th**
12 to 12+6	19.0	21.0	24.0	27.0	33.0	34.0	35.0
13 to 13+6	26.0	27.0	28.0	33.0	37.0	38.0	38.0
14 to 14+6	32.0	33.0	33.0	38.0	41.0	42.0	44.0
15 to 15+6	36.0	38.0	39.0	42.0	47.0	49.0	54.0
16 to 16+6	40.0	41.0	42.0	46.0	50.0	52.0	52.0
17 to 17+6	42.8	45.0	47.0	51.0	55.0	57.0	59.0
18 to 18+6	45.0	47.0	51.0	55.0	59.6	68.0	70.0
19 to 19+6	49.0	52.0	54.3	58.0	64.0	66.9	69.5
20 to 20+6	56.0	57.0	59.0	63.0	68.0	70.0	73.0
21 to 21+6	59.0	61.0	63.0	67.0	72.0	74.0	77.0
22 to 22+6	63.0	65.0	66.0	70.0	75.0	76.1	77.0
23 to 23+6	64.0	66.0	69.0	74.0	79.0	81.0	83.0
24 to 24+6	69.0	71.0	74.0	78.0	83.0	86.0	87.0
25 to 25+6	72.1	75.0	78.0	83.0	88.0	90.6	92.0
26 to 26+6	76.0	78.0	81.0	86.0	92.0	94.0	97.0
27 to 27+6	79.9	81.0	83.3	90.0	97.0	100.0	101.0
28 to 28+6	84.0	86.0	89.0	94.0	99.0	100.0	101.0
29 to 29+6	79.8	85.3	90.0	96.0	101.0	102.0	105.0
30 to 30+6	87.0	91.0	93.0	99.0	104.0	107.0	109.2
31 to 31+6	88.0	93.0	96.0	102.0	107.0	108.0	109.0
32 to 32+6	95.0	97.0	99.0	104.0	110.0	111.0	112.0
33 to 33+6	97.0	99.0	102.0	107.0	111.0	113.0	114.0
34 to 34+6	99.0	101.0	104.0	109.0	115.0	116.0	118.0
35 to 35+6	101.0	103.0	105.0	111.0	116.0	117.0	118.0
36 to 36+6	105.0	105.0	106.0	113.0	118.0	120.0	122.0
37 to 37+6	104.0	105.0	108.3	116.0	119.7	122.0	124.0
38 to 38+6	108.0	109.0	111.0	117.0	122.0	125.0	126.0
39 to 39+6	110.0	111.0	113.6	119.0	125.0	129.0	131.0
40 to 40+6	112.0	112.7	115.0	119.0	125.0	129.4	132.8
41 to 41+6	110.0	114.0	116.0	121.0	127.0	127.0	127.8
42 to 42+6	106.0	106.0	106.0	123.0	134.0	134.0	134.0

This means that 10% of the fetuses at 20 to 20 + 6 had a mean occipitofrontal diameter less than 59 millimeters, while 90% had a mean occipitofrontal diameter greater than 59 millimeters. Similarly, the 97th percentile of occipitofrontal diameter at 36 to 36 + 6 is 118 millimeters. Hence 97% of fetuses at 36 to 36 + 6 had a mean occipitofrontal diameter less than 118 millimeters while 3% had a mean occipitofrontal diameter greater than 118 millimeters. The standard score or z-score of occipitofrontal diameter measurements in 13,740 fetuses ranging from 12 – 42 weeks of gestation is shown in Tab.6.12. The z-score enables us to look at occipitofrontal diameter measurements in each gestational age and see how they compare on the same standard; taking into account the mean and standard deviation of each gestational age. For example, occipitofrontal diameter measurements at 15 weeks are 0.0104 standard deviations from the mean while measurements at 37 weeks are 0.0000 standard deviations from the mean. Again, from the above z-score table, it can be seen that the occipitofrontal diameter measurements at 38 weeks gestation are – 0.0075 standard deviations from the mean.

When occipitofrontal diameter data of 13,740 fetuses was subjected to skewness analysis at different gestational age ranging from 12 – 42 weeks (Fig. 6.29), it can be seen that the distribution of occipitofrontal diameter measurements has a longer "tail" to the right of the central maximum than to the left or is skewed to the right from 13 – 24, 26, 38, 39 and 40 weeks. From 12, 13, 25, 27 – 37, 41 and 42weeks, the distribution has a longer "tail" to the left of the central maximum than to the right or is skewed to the left. By the time pregnancy reaches term, the distribution becomes skewed to the right before skewing again to the left as from 41 weeks. When the occipitofrontal diameter data was subjected to kurtosis analysis (Fig. 6.30), the analysis was found to be leptokurtic at 14, 15, 18, 19, 29 and 38 weeks of gestation while mesokurtic at the other weeks of gestation. The coefficient of dispersion of occipitofrontal diameter data of 13,740 fetuses at different gestational age shows a decrease in value as gestational age advances except at 18 and 42 weeks where it peaks (Fig. 6.31). The occipitofrontal diameter scattergram in Fig. 6.45 shows that there are very few bad data points or outliers in the occipitofrontal diameter measurements of 13,740 fetuses. The outliers are more from 26 – 42 weeks of gestation. This shows the pattern of growth recognized for neural tissue which suggests growth of brain.

Tab. 6.12 *Standard score (z-score) of occipitofrontal diameter measurements in 13,740 Nigerian fetuses in Jos ranging from 12 – 42 weeks gestation.*

GA (weeks, days)	Fetuses (n)	Mean z-score
12 to 12+6	49	5.52E-03
13 to 13+6	384	-6.16E-03
14 to 14+6	371	6.11E-03
15 to 15+6	351	1.04E-02
16 to 16+6	505	-9.32E-03
17 to 17+6	427	-5.30E-03
18 to 18+6	446	3.93E-03
19 to 19+6	282	-3.21E-03
20 to 20+6	553	-2.63E-03
21 to 21+6	400	-4.88E-03
22 to 22+6	398	-5.53E-03
23 to 23+6	478	-7.93E-03
24 to 24+6	520	-5.43E-03
25 to 25+6	388	-1.16E-03
26 to 26+6	511	-7.61E-03
27 to 27+6	432	-7.54E-03
28 to 28+6	548	9.84E-03
29 to 29+6	484	2.09E-03
30 to 30+6	625	-4.13E-03
31 to 31+6	523	-6.80E-03
32 to 32+6	583	-0.50846
33 to 33+6	516	-9.73E-03
34 to 34+6	744	-0.28427
35 to 35+6	739	3.66E-03
36 to 36+6	599	-4.29E-03
37 to 37+6	532	8.00E-05
38 to 38+6	481	-7.57E-03
39 to 39+6	525	3.05E-03
40 to 40+6	252	5.99E-03
41 to 41+6	72	-8.81E-03
42 to 42+6	22	4.43E-03
Total	13,740	

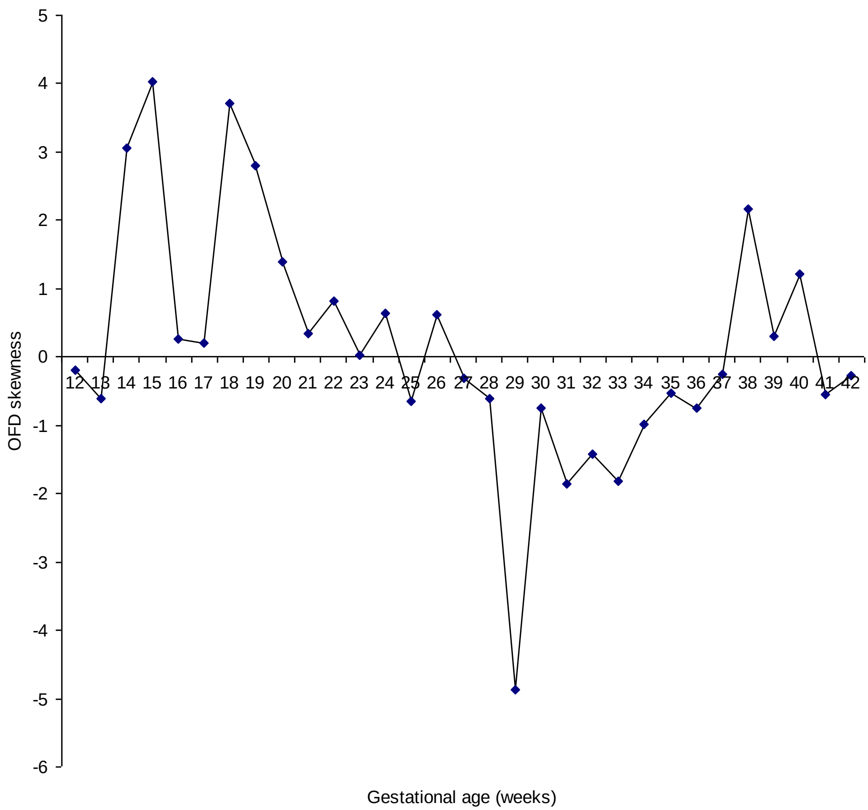

Fig. 6.29 *Occipitofrontal diameter data of 13,740 fetuses subjected to Skewness analysis at different gestational age ranging from 12 – 42 weeks.*

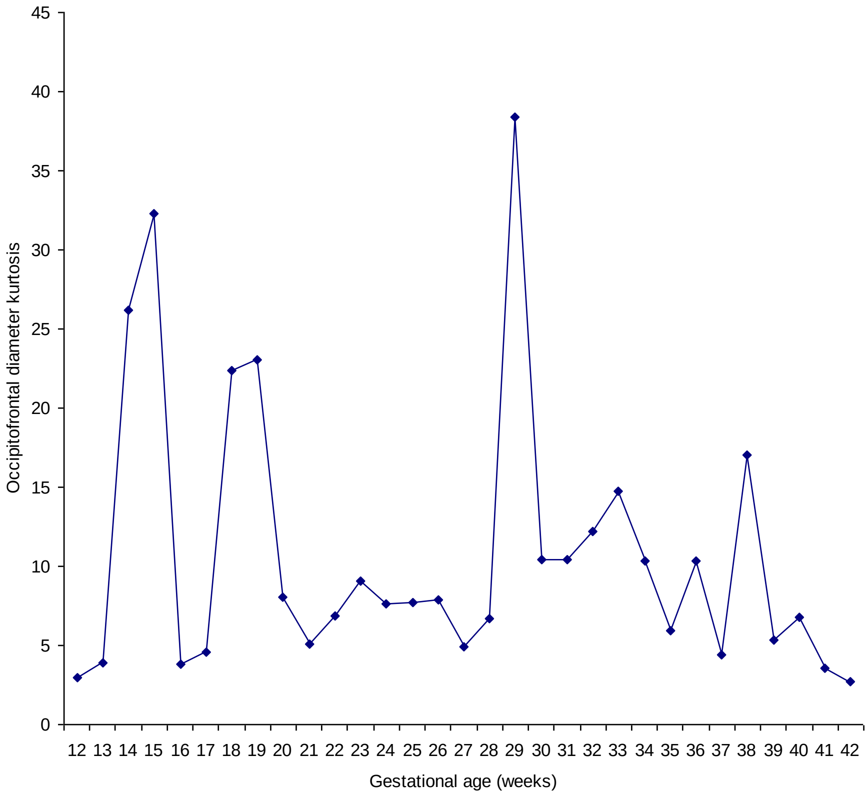

Fig. 6.30 *Occipitofrontal diameter data of 13,740 fetuses subjected to kurtosis analysis at different gestational age ranging from 12 – 42 weeks.*

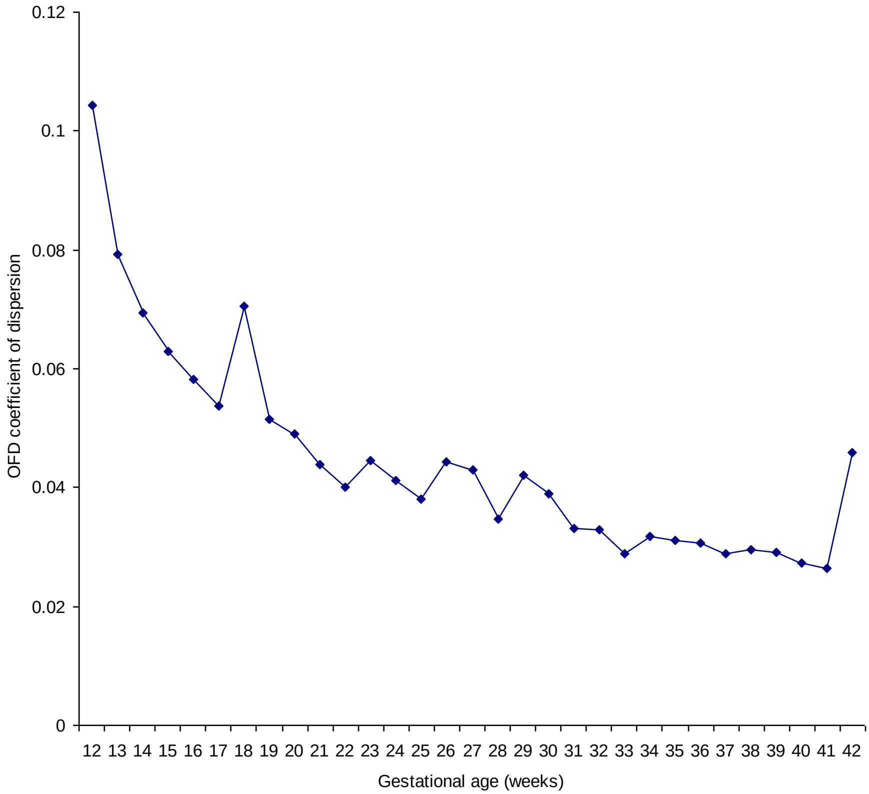

Fig. 6.31 *Occipitofrontal diameter coefficient of dispersion in 13,740 fetuses of gestational ages between 12 to 42 weeks.*

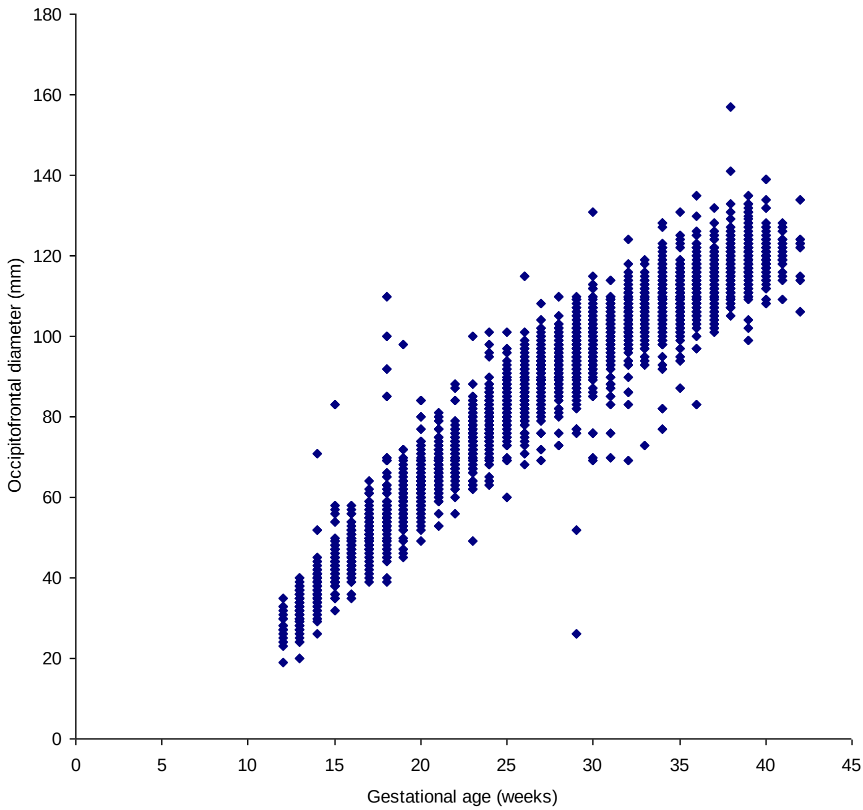

Fig. 6.32 *Scattergram of 13,740 fetal occipitofrontal diameter measurements from 12 – 42 weeks gestation.*

In Fig. 6.33, mean occipitofrontal diameter is plotted against gestational age with error bars showing standard deviation. Mathematical modeling of occipitofrontal diameter data demonstrated that the best-fitted regression model is as shown in Fig. 6.34. There is a positive polynomial correlation between gestational age and occipitofrontal diameter with a correlation of determination of $r^2 = 0.9996$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the third order polynomial regression equation $y = -0.001x^3 + 0.0137x^2 + 4.671x - 27.99$ where y is the occipitofrontal diameter in millimeters and x is the gestational age in weeks.

When monthly mean values of occipitofrontal diameter are plotted against gestational age in months, a positive polynomial correlation between gestational age and occipitofrontal diameter with a correlation of determination of $r^2 = 0.9997$ ($P < 0.0001$) in Nigerian fetuses in Jos was found (Fig. 6.35). The relationship is best described by the second order polynomial regression equation $y = -1.2964x^2 + 32.011x - 70.179$ where y is the occipitofrontal diameter in millimeters and x is the gestational age in months.

When other fetal anthropometric parameters like head circumference, biparietal diameter, abdominal circumference, femur length and weight are plotted against occipitofrontal diameter certain hidden relationships can be forced out. For example, Fig.6.36 shows the relationship of occipitofrontal diameter with biparietal diameter. From the graph, it can be seen that there is a positive linear correlation between biparietal diameter and occipitofrontal diameter with a correlation of determination of $r^2 = 0.9997$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the linear regression equation $y = 0.8046x - 0.9072$ where y is the biparietal diameter in millimeters and x is the occipitofrontal diameter in millimeters. Fig. 6.37 shows relationship of occipitofrontal diameter with head circumference which has regression equation of $y = 2.882x + 0.1487$; $r^2 = 1$ ($P<0.0001$). Fig. 6.38 shows relationship of occipitofrontal diameter with abdominal circumference. From the graph, it can be seen that there is a positive polynomial correlation between abdominal circumference and occipitofrontal diameter with a correlation of determination of $r^2 = 0.9993$ ($P < 0.0001$) in Nigerian fetuses in Jos.

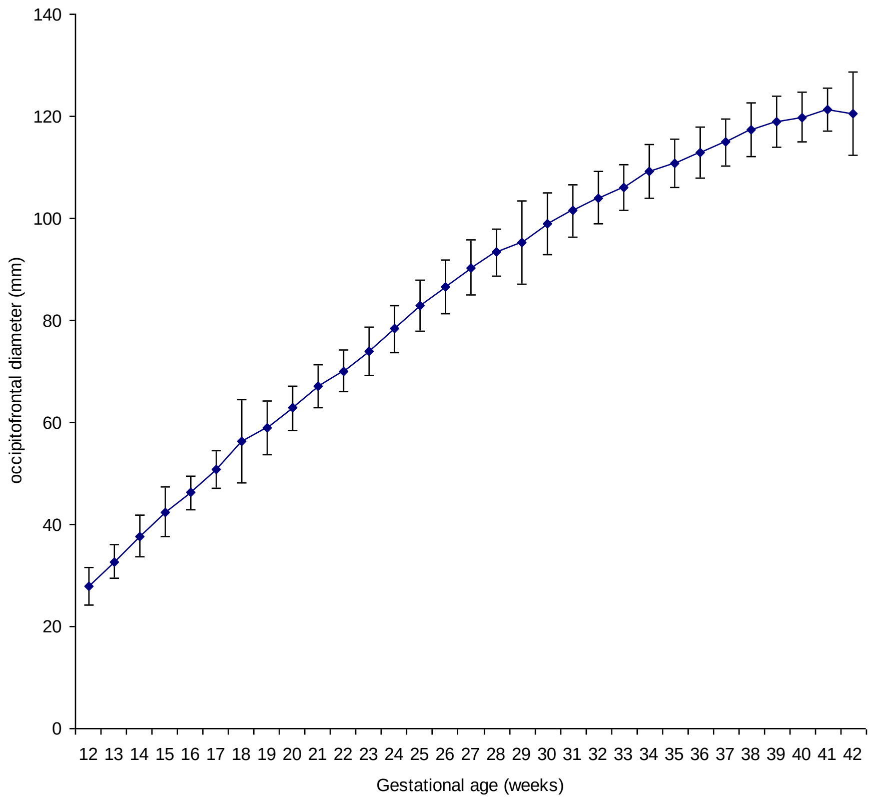

Fig. 6.33 *Mean fetal occipitofrontal diameter values in 13,740 fetuses of women at different gestational ages between 12 – 42 weeks. The vertical bars show the values of ±SD.*

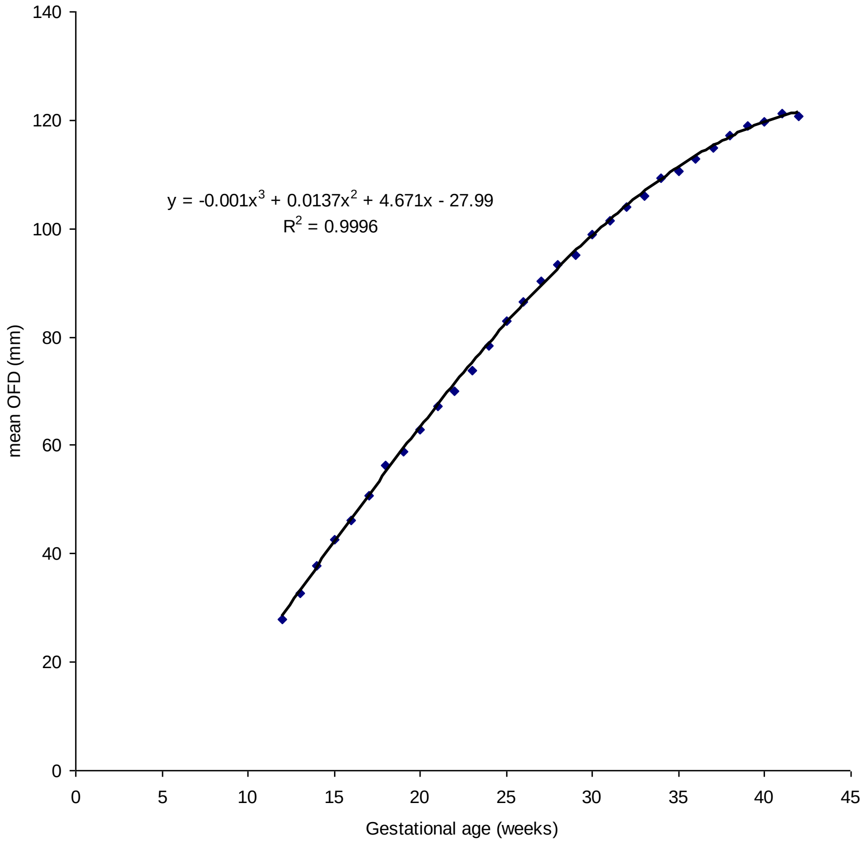

Fig. 6.34 *Correlation and regression equation of mean occipitofrontal diameter values in 13,740 Nigerian fetuses in Jos plotted against gestational age in weeks*.

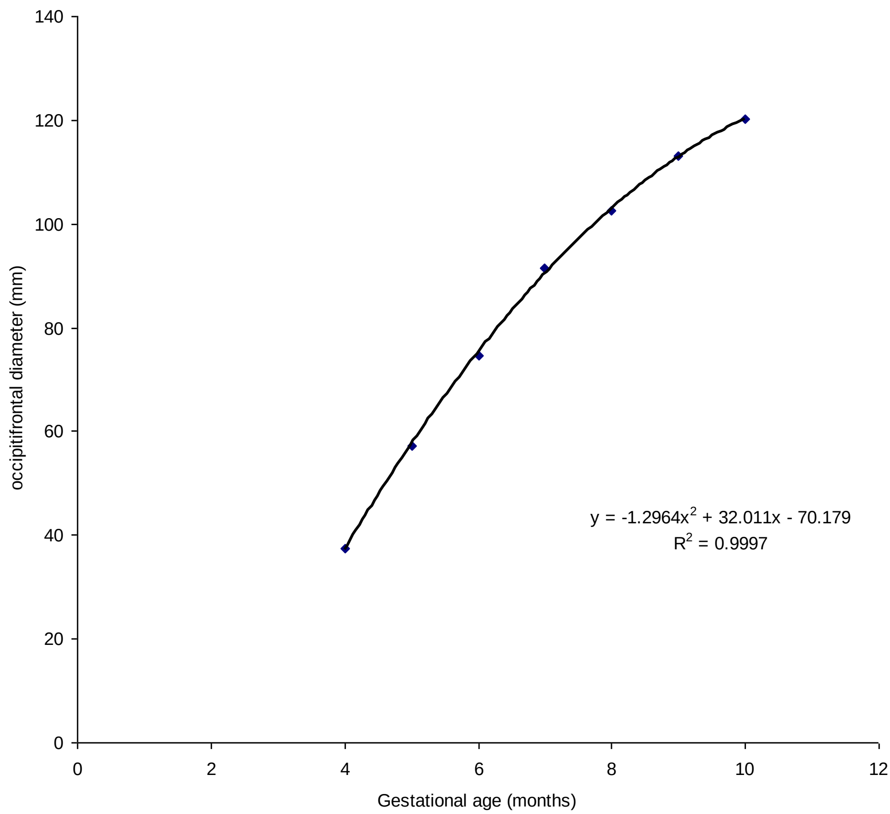

Figure 6.35 *Correlation and regression equation of mean occipitofrontal diameter values in 13,740 Nigerian fetuses in Jos plotted against gestational age in months.*

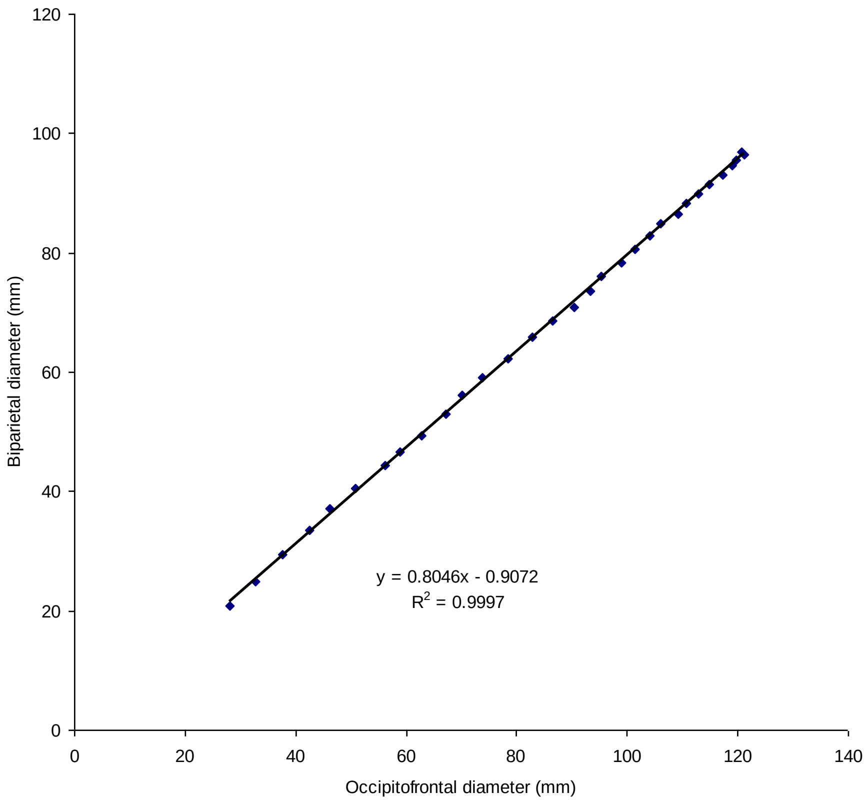

Fig. 6.36 *Correlation and regression equation of mean occipitofrontal diameter values in 13,740 Nigerian fetuses in Jos plotted against biparietal diameter.*

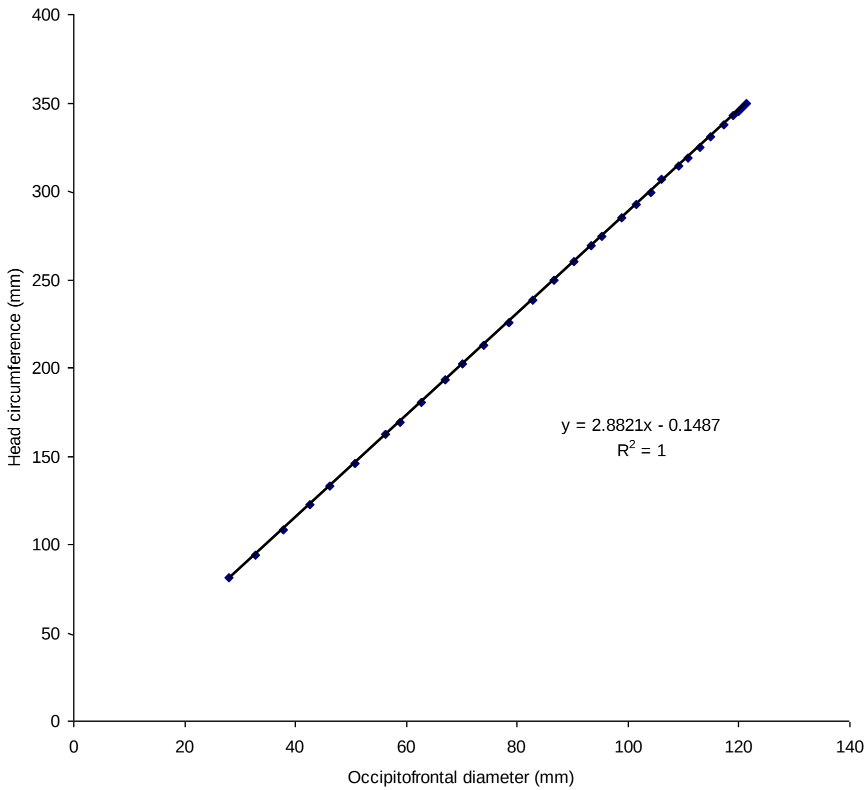

Fig. 6.37 *Correlation and regression equation of mean head circumference values in 13,740 Nigerian fetuses in Jos plotted against occipitofrontal diameter.*

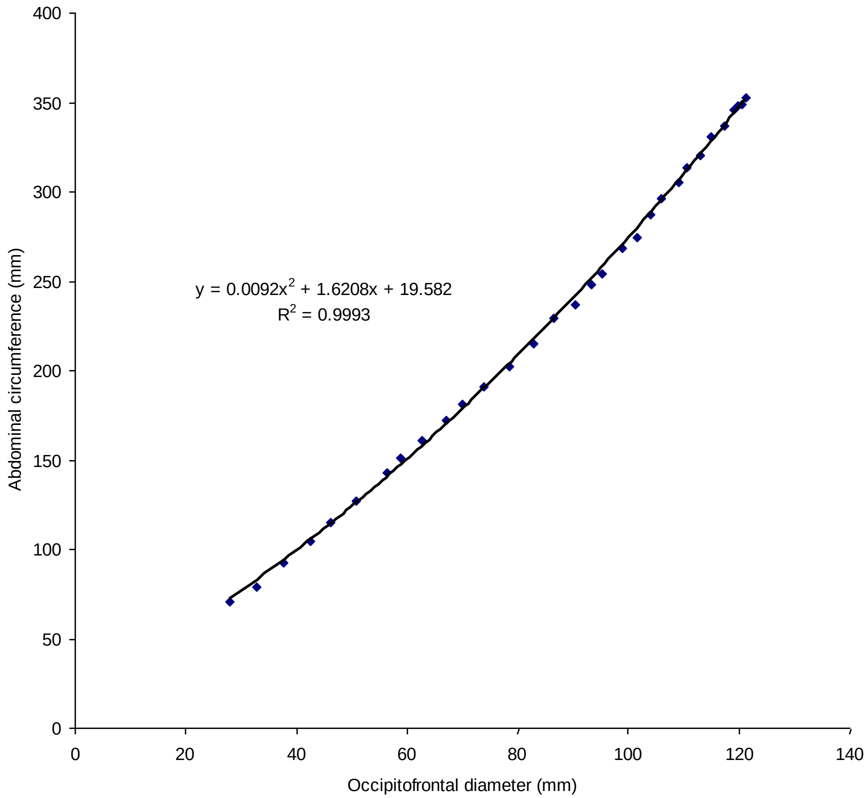

Fig. 6.38 *Correlation and regression equation of mean occipitofrontal diameter values in 13,740 Nigerian fetuses in Jos plotted against abdominal circumference.*

The relationship is best described by the quadratic regression equation $y = 0.0092x^2 + 1.6208x + 19.582$ where y is the abdominal circumference in millimeters and x is the occipitofrontal diameter in millimeters.

Fig. 6.39 shows relationship between femur length and occipitofrontal diameter. There is a positive polynomial correlation between femur length and occipitofrontal diameter with a correlation of determination of $r^2 = 0.9945$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the quadratic regression equation $y = 0.0025x^2 + 0.3313x + 1.5192$

where y is the femur length in millimeters and x is the occipitofrontal diameter in millimeters. Fig. 6.40 shows the relationship between fetal weight which is strongly correlated with fetal nutrition and occipitofrontal diameter. The graph shows that there is a positive polynomial correlation between fetal weight and occipitofrontal diameter with a correlation of determination of $r^2 = 0.9989$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the third order regression equation $y = 0.0071x^3 – 1.0218x^2 + 57.868x – 925.93$ where y is the fetal weight in grams and x is the occipitofrontal diameter in millimeters.

Occipitofrontal diameter centile values for 5^{th}, 50^{th} and 95^{th} are plotted as shown in Fig. 6.41. In Fig. 6.42, the 3rd, 50^{th} and 97^{th} are smoothened into a growth chart which can be utilized to determine occipitofrontal diameter growth and of course brain size development, which is strongly related to intelligence and wellness, using occipitofrontal diameter. Fig.6. 43 is a graphical display showing the growth rate of the measured fetal occipitofrontal diameter at gestational age ranging from 12 – 42 weeks. It is clear from this graph that growth rate is much higher in the early stages of development than the late ones which precede term.

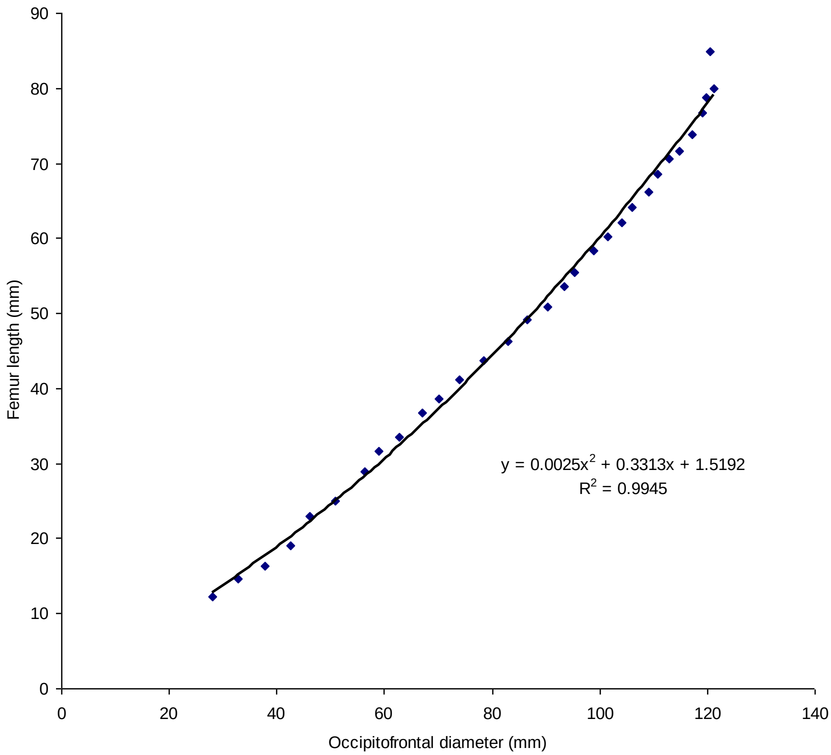

Fig. 6.39 *Correlation and regression equation of mean occipitofrontal diameter values in 13,740 Nigerian fetuses in Jos plotted against femur length.*

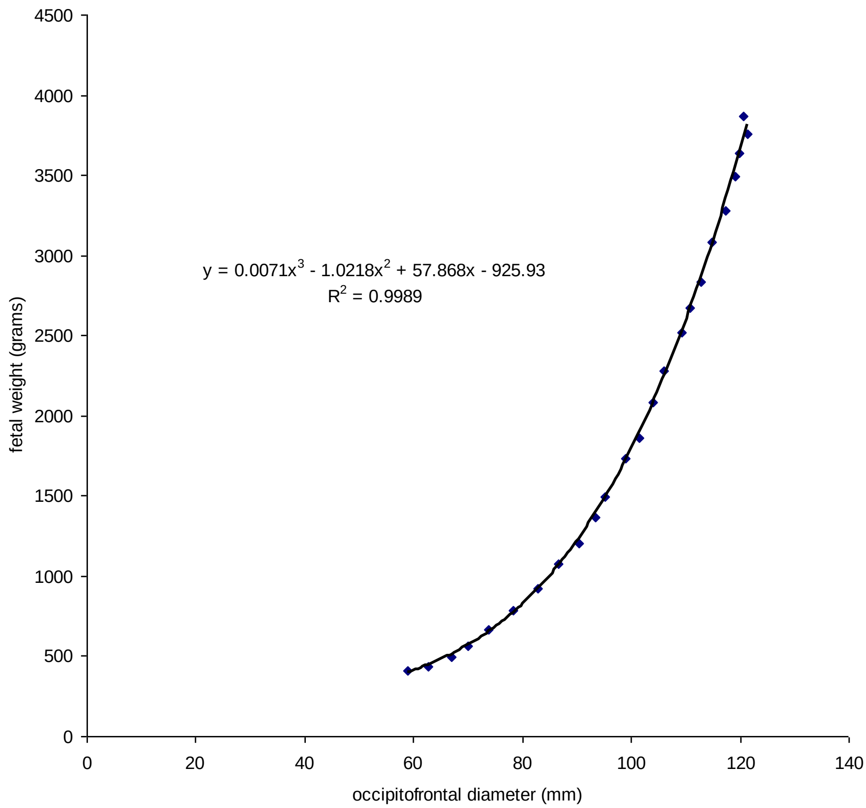

Fig. 6.40 *Correlation and regression equation of mean occipitofrontal diameter values in 13,740 Nigerian fetuses in Jos plotted against fetal weight.*

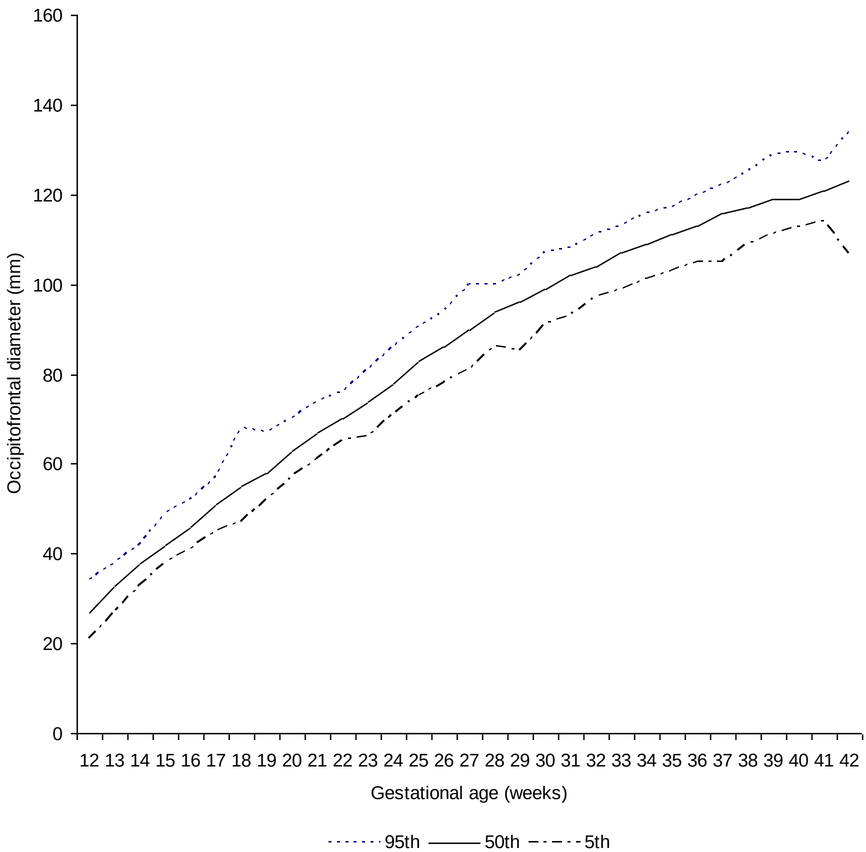

Fig. 6.41 *Fifth, 50th and 97th centiles for occipitofrontal diameter in 13,740 fetuses at different gestational ages from 12 to 42 weeks.*

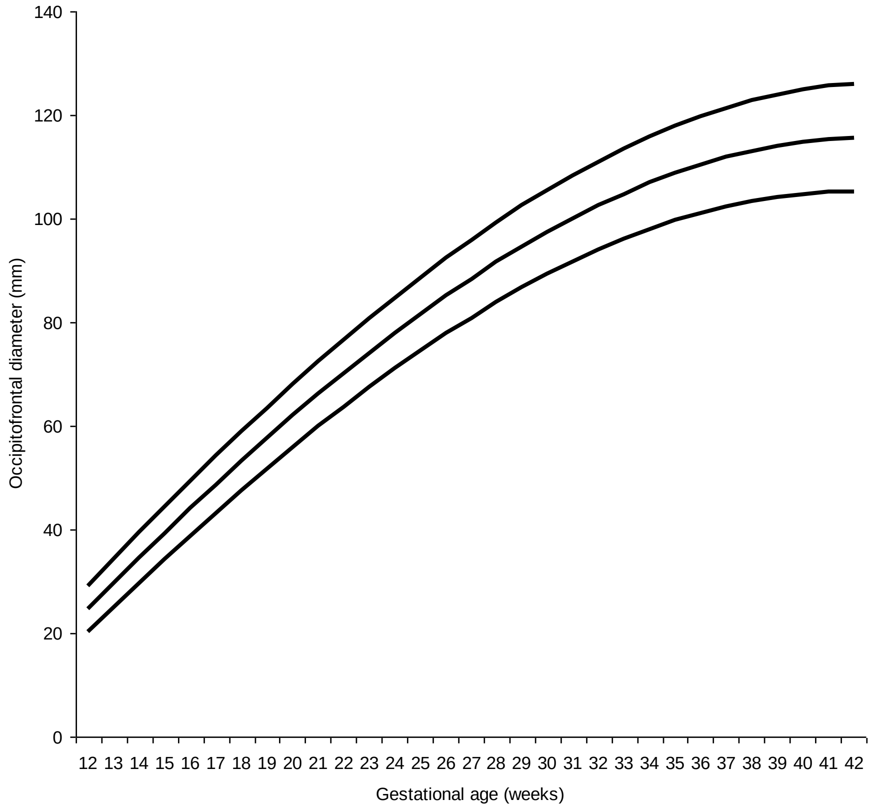

Fig. 6.42 *Curves created from 3rd, 50th and 97th fetal occipitofrontal diameter centiles.*

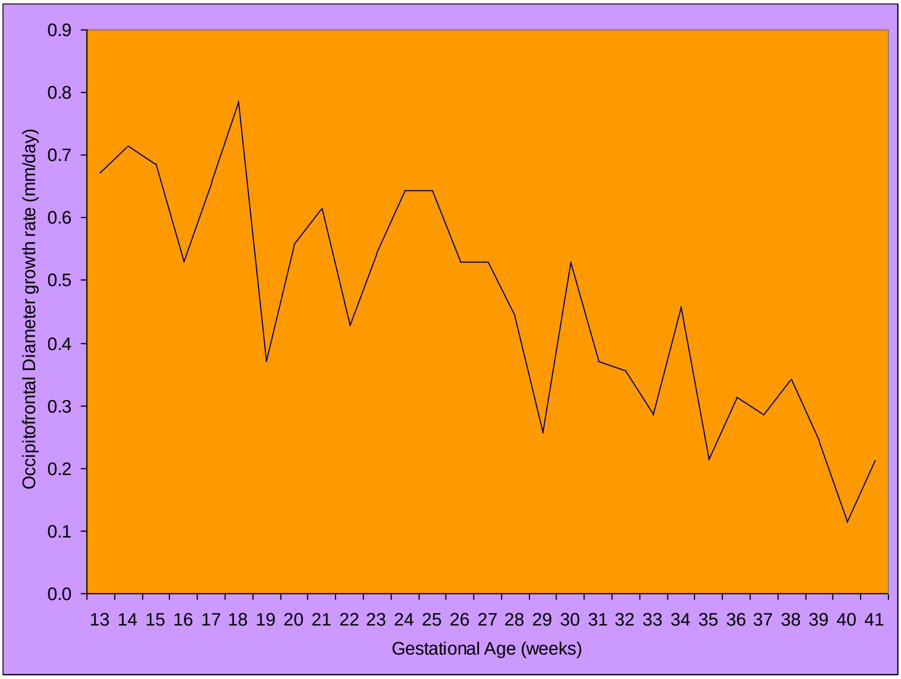

Fig. 6.43 *Growth velocity pattern of occipitofrontal diameter in 13,740 Nigerian fetuses in Jos ranging from 12 – 42 weeks.*

Biometrics of Fetal Abdominal Circumference

The mean fetal abdominal circumference values at each week of gestation from 12 – 42 are as shown in Tab. 6.13. This table gives the mean values of fetal abdominal circumference measurements for each gestational age in weeks from 12 – 42 weeks together with their corresponding standard deviations and standard errors of mean.

Variation in the measurements of fetal abdominal circumference was found to be 2mm and above at weeks 18, 21, 31, 35, 39 and 42. The highest mean abdominal circumference was achieved at 42 weeks and the lowest mean abdominal circumference was at 12 weeks. With the arithmetic mean, one has some idea of the kind of numbers it represents, but the whole story is still a mystery. To clear up the mystery of the hidden numbers that made up a mean, the standard deviation is necessary. For example, the mean abdominal circumference at 36 weeks is 320.0mm plus 1.8mm or 320.0mm minus 1.8mm. This means 2 out of 3 measurements of abdominal circumference at 36 weeks, approximately 399 abdominal circumference measurements in a class of 599, should be between 318.2mm and 321.8mm. Since the standard error of mean at 36 weeks is 0.0mm, it is telling us that the real mean abdominal circumference of fetuses in Jos at 41 weeks is 320.0mm (320.0mm plus or minus 0.0mm). It can also be seen that the standard error of mean for each week of gestation from 12 – 42 is very small suggesting that the sample mean is very close to the population mean. For example, at 13 weeks gestation, the mean fetal abdominal circumference was 79.2mm while the standard error of mean was 1.2. This means that the difference between the mean abdominal circumferences of the sample of fetuses at 13 weeks is just 1.2mm different from that of the population of fetuses at 13 weeks gestation. The geometric means (Tab. 6.14) of all sets of measurements from 12 – 42 weeks are less than their arithmetic means but greater than their harmonic means indicating that all the values of fetal abdominal circumference measurements were not identical.

Tab. 6.15 gives the centile values of fetal abdominal circumference measurements. This table gives the 3^{rd}, 5^{th}, 10^{th}, 50^{th}, 90^{th}, 95^{th}, and 97^{th} centile values for fetal abdominal circumference measured at different gestational age ranging from 12 – 42 weeks. For example, it can be seen from the table that the 5^{th} percentile of abdominal circumference at 26 to 26 + 6 weeks gestation is 20.7 centimeters.

Tab. 6.13 *Frequency distribution table of fetal abdominal circumference measurements showing the arithmetic mean, standard deviation and standard error of mean from 12 – 42 weeks gestation.*

GA (week, days)	Fetuses (n)	Mean AC (mm)	SD	SE
12 to 12+6	49	70.4	1.5	0.2
13 to 13+6	384	79.2	1.2	0.0
14 to 14+6	371	92.5	1.2	0.0
15 to 15+6	351	104.8	1.3	0.0
16 to 16+6	505	115.3	1.3	0.0
17 to 17+6	427	127.4	1.7	0.0
18 to 18+6	446	142.7	2.4	0.1
19 to 19+6	282	151.1	1.7	0.1
20 to 20+6	553	160.7	1.6	0.0
21 to 21+6	400	172.5	2.3	0.1
22 to 22+6	398	181.2	1.5	0.1
23 to 23+6	478	190.7	1.8	0.0
24 to 24+6	520	202.0	1.6	0.0
25 to 25+6	388	215.4	1.7	0.0
26 to 26+6	511	229.3	1.8	0.0
27 to 27+6	432	236.7	2.0	0.0
28 to 28+6	548	248.0	1.7	0.0
29 to 29+6	484	254.3	1.9	0.0
30 to 30+6	625	268.7	1.9	0.0
31 to 31+6	523	274.7	2.0	0.0
32 to 32+6	583	287.1	1.6	0.0
33 to 33+6	516	296.0	1.9	0.0
34 to 34+6	744	305.0	1.9	0.0
35 to 35+6	739	313.2	2.0	0.0
36 to 36+6	599	320.0	1.8	0.0
37 to 37+6	532	330.5	1.8	0.1
38 to 38+6	481	336.8	1.7	0.0
39 to 39+6	525	345.6	2.2	0.0
40 to 40+6	252	348.4	1.9	0.1
41 to 41+6	72	352.4	1.3	0.2
42 to 42+6	22	349.0	2.2	0.5
Total	13,740			

Tab. 6.14 *Frequency distribution table of fetal abdominal circumference measurements showing arithmetic mean, geometric mean and harmonic mean from 12 – 42 weeks gestation.*

GA (week, days)	Number of fetuses (n)	Arithmetic mean (mm)	Geometric mean (mm)	Harmonic mean (mm)
12 to 12+6	49	7.042857	6.900781	6.770617
13 to 13+6	384	7.923438	7.82983	7.733103
14 to 14+6	371	9.249057	9.171251	9.087093
15 to 15+6	351	10.47692	10.40627	10.34549
16 to 16+6	505	11.5299	11.46782	11.41118
17 to 17+6	427	12.737	12.65461	12.57686
18 to 18+6	446	14.26883	14.11921	13.99722
19 to 19+6	282	15.11277	15.02775	14.94986
20 to 20+6	553	16.06546	15.98812	15.91212
21 to 21+6	400	17.2465	17.11336	16.98076
22 to 22+6	398	18.11658	18.05408	17.99383
23 to 23+6	478	19.06862	18.97901	18.8767
24 to 24+6	520	20.20365	20.13879	20.0751
25 to 25+6	388	21.53918	21.47404	21.40784
26 to 26+6	511	22.92955	22.86071	22.79436
27 to 27+6	432	23.6669	23.58506	23.50435
28 to 28+6	548	24.79635	24.74141	24.68774
29 to 29+6	484	25.42975	25.34406	25.23957
30 to 30+6	625	26.86768	26.80438	26.74241
31 to 31+6	523	27.474	27.39667	27.31487
32 to 32+6	583	28.70892	28.66116	28.6117
33 to 33+6	516	29.60368	29.54634	29.48943
34 to 34+6	744	30.50054	30.43813	30.37043
35 to 35+6	739	31.31651	31.25593	31.19619
36 to 36+6	599	31.99683	31.94766	31.89678
37 to 37+6	532	33.04906	32.99531	32.93646
38 to 38+6	481	33.68129	33.63824	33.59433
39 to 39+6	525	34.55905	34.48941	34.41487
40 to 40+6	252	34.83611	34.78634	34.73609
41 to 41+6	72	35.23889	35.2147	35.19038
42 to 42+6	22	34.90454	34.83539	34.7663
Total	13740			

Tab. 6.15 *Fetal abdominal circumference centiles from 12 – 42 weeks.*

	Abdominal circumference centiles (cm)						
Gestational age (weeks, days)	**3rd**	**5th**	**10th**	**50th**	**90th**	**95th**	**97th**
12 to 12+6	5.3	5.4	5.4	6.5	9.5	10.1	10.1
13 to 13+6	5.8	5.9	6.2	7.9	9.5	9.9	10.1
14 to 14+6	7.1	7.5	8.0	9.2	10.7	11.2	11.8
15 to 15+6	8.7	9.1	9.3	10.3	11.8	12.4	13.3
16 to 16+6	9.9	10.0	10.2	11.3	13.1	13.5	14.3
17 to 17+6	10.4	10.7	11.3	12.4	14.5	15.8	16.8
18 to 18+6	11.6	12.0	12.6	13.8	15.8	17.9	19.1
19 to 19+6	12.4	12.9	13.7	14.9	16.9	17.8	18.2
20 to 20+6	13.4	13.6	14.3	15.9	18.0	19.0	19.4
21 to 21+6	14.9	14.9	15.3	17.0	19.1	20.0	20.8
22 to 22+6	15.9	16.2	16.5	17.9	20.0	20.8	21.4
23 to 23+6	15.9	16.6	17.2	19.0	21.3	21.8	22.8
24 to 24+6	17.0	17.6	18.5	20.0	22.1	23.0	23.7
25 to 25+6	18.7	19.2	19.4	21.4	23.7	24.5	25.1
26 to 26+6	20.0	20.7	21.0	22.6	25.1	26.1	26.8
27 to 27+6	20.4	20.9	21.6	23.5	26.2	27.3	28.2
28 to 28+6	21.8	22.6	23.0	24.6	26.7	27.9	28.5
29 to 29+6	22.5	22.6	23.3	25.4	27.8	28.3	28.5
30 to 30+6	23.9	24.1	24.7	26.7	29.1	29.8	30.2
31 to 31+6	22.9	24.1	25.5	27.6	29.7	30.0	30.5
32 to 32+6	25.9	26.3	26.8	28.6	30.5	31.1	31.9
33 to 33+6	26.1	26.4	27.4	29.6	31.6	32.0	32.9
34 to 34+6	27.3	27.8	28.4	30.5	32.6	33.2	33.9
35 to 35+6	28.1	28.3	29.0	31.3	33.4	34.2	35.5
36 to 36+6	29.1	29.4	29.9	32.0	34.0	35.0	35.4
37 to 37+6	29.5	30.2	31.0	33.2	35.1	35.9	36.6
38 to 38+6	30.9	31.2	31.8	33.6	35.9	36.4	36.9
39 to 39+6	30.5	31.0	32.3	34.7	36.9	38.2	38.8
40 to 40+6	30.5	31.4	33.1	34.6	37.8	38.4	38.5
41 to 41+6	32.3	32.9	33.7	35.1	37.0	37.3	37.3
42 to 42+6	30.9	30.9	31.5	34.9	38.7	38.7	38.7

This means that 5% of the fetuses at 26 to 26 + 6 had a mean abdominal circumference less than 20.7 centimeters, while 95% had a mean abdominal circumference greater than 20.7 centimeters. Similarly, the 90th percentile of abdominal circumference at 33 to 33 + 6 weeks is 31.6 centimeters. Hence 90% of fetuses at 33 to 33 + 6 weeks had a mean abdominal circumference less than 31.6 centimeters while 10% had a mean abdominal circumference greater than 31.6 centimeters.

The standard score or z-score of abdominal circumference measurements in 13,740 fetuses ranging from 12 – 42 weeks of gestation is shown in Tab. 6.16. The z-score enables one to look at abdominal circumference measurements at each gestational age and see how they compare on the same standard; taking into account the mean and standard deviation of each gestational age. For example, abdominal circumference measurements at 28 weeks are – 0.0215 standard deviations from the mean while measurements at 36 weeks are – 0.0175 standard deviations from the mean. Again, from the above z-score table, it can be seen that the abdominal circumference measurements at 38 weeks gestation are 0.00758 standard deviations from the mean.

When abdominal circumference data of 13,740 fetuses was subjected to skewness analysis at different gestational age ranging from 12 – 42 weeks (Fig. 6.44), it can be seen that the distribution of abdominal circumference measurements has a longer "tail" to the right of the central maximum than to the left or is skewed to the right from 12, 14, 15, 18, 19, 20, 21, 22 and 39 weeks. In the remaining weeks, the distribution has a longer "tail" to the left of the central maximum than to the right or is skewed to the left. By the time pregnancy reaches term, the distribution becomes skewed to the right before skewing again to the left as from 41 weeks. When the abdominal circumference data was subjected to kurtosis analysis (Fig.6. 45), the analysis was found to be leptokurtic at 15, 18, 19 and 21 weeks of gestation while at other weeks of gestation, the distribution was mesokurtic. The coefficient of dispersion (fig 46) of abdominal circumference data of 13,740 fetuses at different gestational age shows a relatively constant pattern except at 20 weeks where it peaks. The abdominal circumference scattergram in Fig.6.47 shows that there are very few bad data points or outliers in the abdominal circumference measurements of 13,740 fetuses.

Tab. 6.16 *Standard score (z-score) of abdominal circumference measurements in 13,740 Nigerian fetuses in Jos ranging from 12 – 42 weeks gestation.*

GA (weeks, days)	Fetuses (n)	Mean z-score
12 to 12+6	49	-2.71565
13 to 13+6	384	-1.75942
14 to 14+6	371	-7.86E-03
15 to 15+6	351	-2.37E-02
16 to 16+6	505	-7.62E-04
17 to 17+6	427	-2.00E-02
18 to 18+6	446	-4.86E-03
19 to 19+6	282	1.63E-02
20 to 20+6	553	-2.84E-02
21 to 21+6	400	-2.47E-02
22 to 22+6	398	-2.28E-02
23 to 23+6	478	-7.67E-03
24 to 24+6	520	2.28E-02
25 to 25+6	388	-4.85E-03
26 to 26+6	511	-2.50E-03
27 to 27+6	432	-1.55E-02
28 to 28+6	548	-2.15E-02
29 to 29+6	484	-1.30E-03
30 to 30+6	625	-1.22E-02
31 to 31+6	523	2.00E-02
32 to 32+6	583	-6.75E-03
33 to 33+6	516	1.94E-02
34 to 34+6	744	2.83E-03
35 to 35+6	739	-1.75E-02
36 to 36+6	599	-1.76E-02
37 to 37+6	532	0.272556
38 to 38+6	481	7.58E-03
39 to 39+6	525	-4.54E-03
40 to 40+6	252	-2.05E-02
41 to 41+6	72	-8.55E-03
42 to 42+6	22	2.07E-02
Total	13,740	

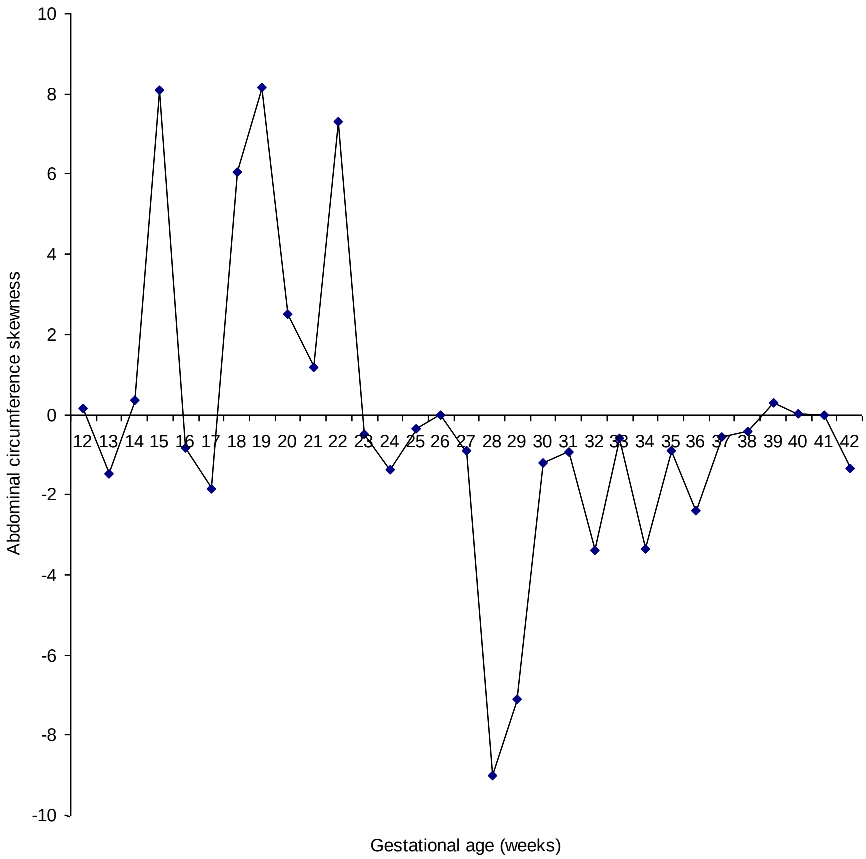

Fig. 6.44 *Abdominal circumference data of 13,740 fetuses subjected to Skewness analysis at different gestational age ranging from 12 – 42 weeks.*

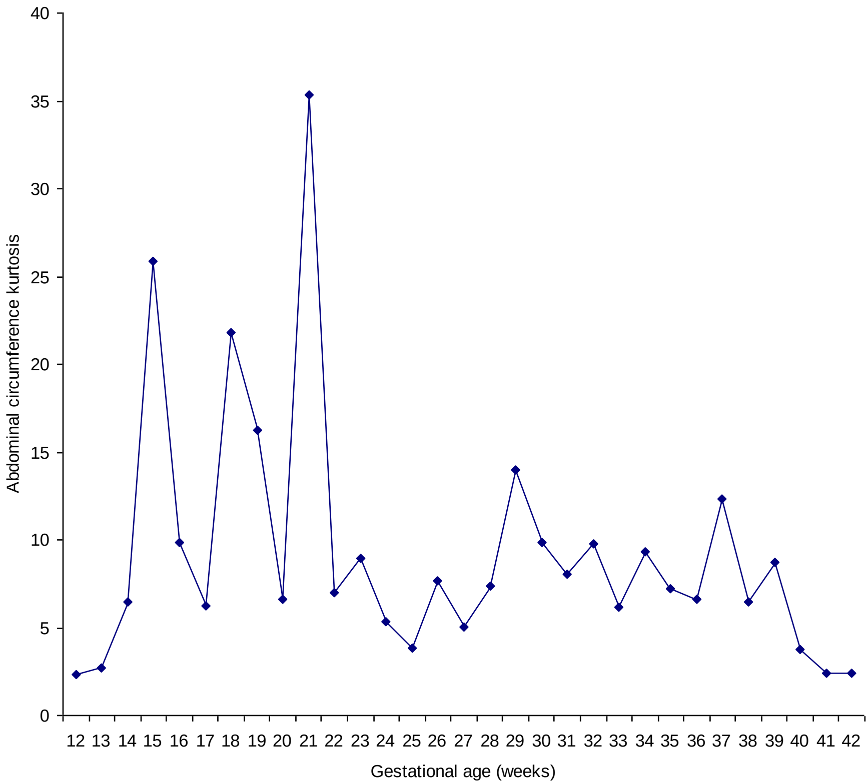

Fig. 6.45 *Abdominal circumference data of 13,740 fetuses subjected to kurtosis analysis at different gestational age ranging from 12 – 42 weeks.*

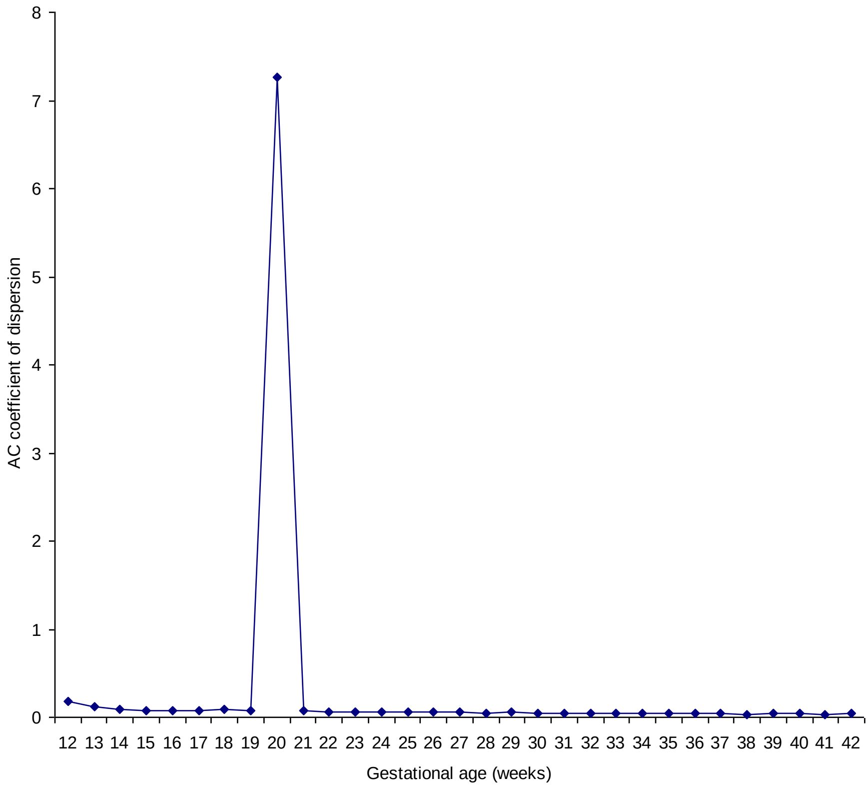

Fig. 6.46 *Abdominal circumference coefficient of dispersion in 13,740 fetuses of gestational ages between 12 to 42 weeks.*

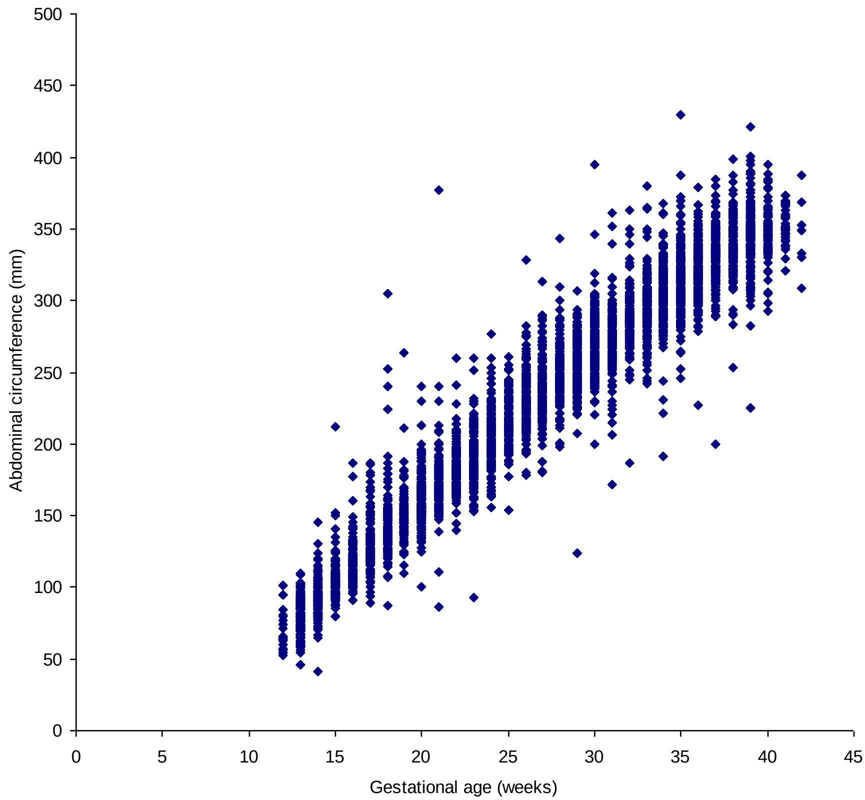

Fig. 6.47 *Scattergram of 13,740 fetal abdominal circumference measurements from 12 – 42 weeks gestation.*

In Fig. 6.48, mean abdominal circumference is plotted against gestational age with error bars showing standard deviation. Mathematical modeling of abdominal circumference data demonstrated that the best-fitted regression model is that shown in Fig. 6.49. From this graph, it can be seen that there is a positive polynomial correlation between gestational age and abdominal circumference with a correlation of determination of $r^2 = 0.9995$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the fourth order polynomial regression equation $y = -0.0004x^4 + 0.0349x^3 - 1.2485x^2 + 30.598x - 172.02$ where y is the abdominal circumference in millimeters and x is the gestational age in weeks. The relationship is best described by the second order polynomial regression equation $y = -2.1893x^2 + 73.861x - 168.99$ where y is the abdominal circumference in millimeters and x is the gestational age in months.

When other fetal anthropometric parameters like head circumference, biparietal diameter, occipitofrontal diameter, femur length and weight are plotted against abdominal circumference certain hidden relationships can be forced out. For example, Fig. 6.50 shows the relationship of abdominal circumference with biparietal diameter. From the graph, it can be seen that there is a positive polynomial correlation between biparietal diameter and abdominal circumference with a correlation of determination of $r^2 = 0.9995$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the quadratic regression equation $y = -0.0003x^2 + 0.3777x - 3.6302$ where y is the biparietal diameter in millimeters and x is the abdominal circumference in millimeters. Fig. 6.51 shows relationship of abdominal circumference with occipitofrontal diameter. From the graph, it can be seen that there is a positive polynomial correlation between occipitofrontal diameter and abdominal circumference with a correlation of determination of $r^2 = 0.9996$ ($P < 0.0001$) in Nigerian fetuses in Jos.

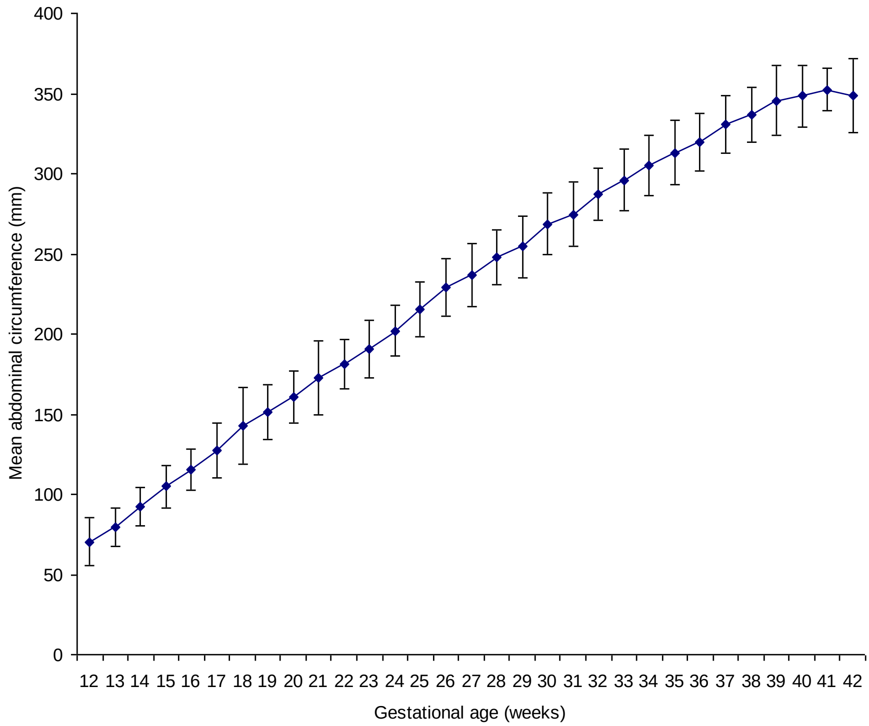

Fig. 6.48 *Mean fetal abdominal circumference values in 13,740 fetuses of women at different gestational ages between 12 – 42 weeks. The vertical bars show the values of ±SD.*

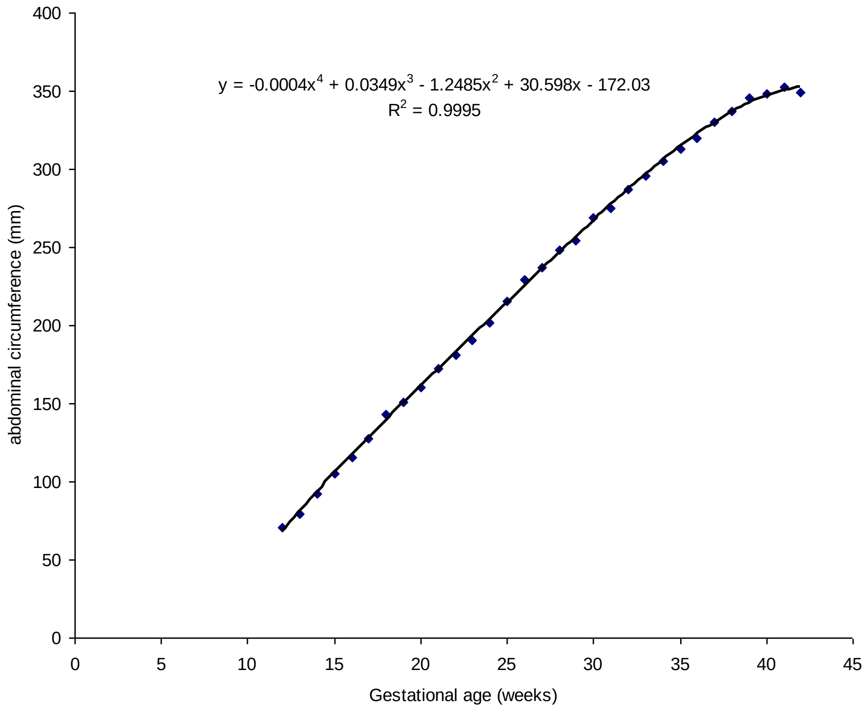

Fig. 6.49 *Correlation and regression equation of mean abdominal circumference values in 13,740 Nigerian fetuses in Jos plotted against gestational age in weeks.*

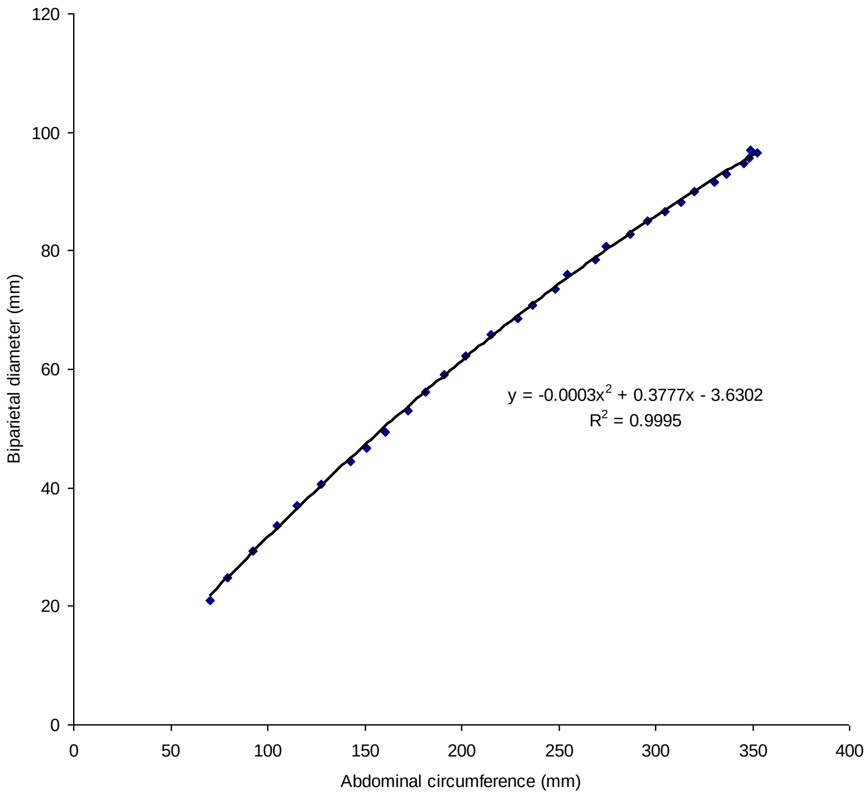

Fig. 6.50 *Correlation and regression equation of mean abdominal circumference values in 13,740 Nigerian fetuses in Jos plotted against biparietal diameter.*

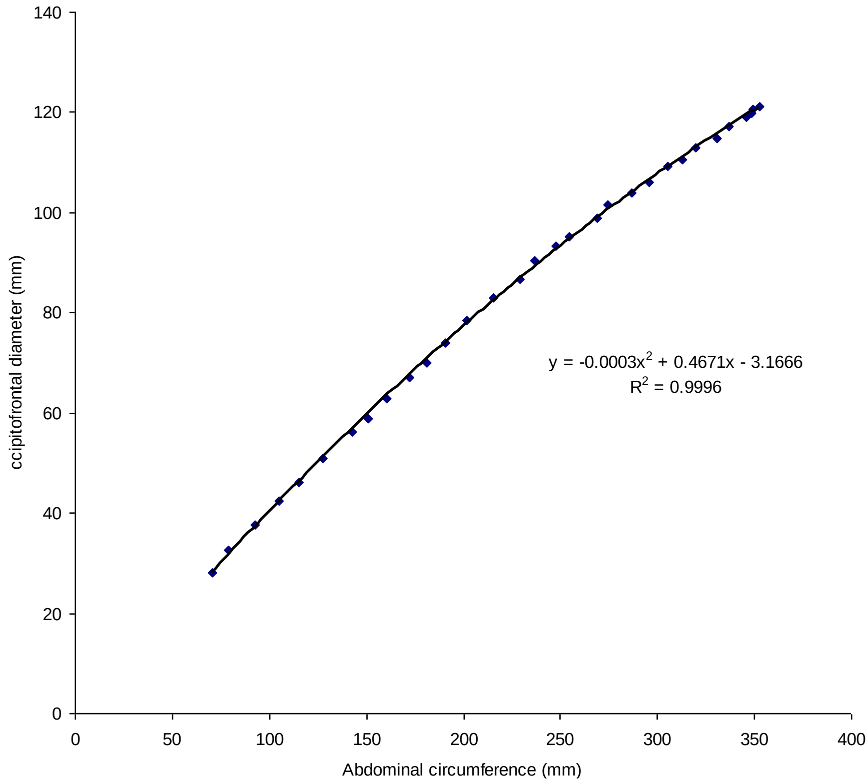

Fig. 6.51 *Correlation and regression equation of mean abdominal circumference values in 13,740 Nigerian fetuses in Jos plotted against occipitofrontal diameter.*

The relationship is best described by the quadratic regression equation $y = -0.0003x^2 + 0.4671x - 3.1666$ where y is the biparietal diameter in millimeters and x is the abdominal circumference in millimeters. Fig. 6.52 shows relationship of abdominal circumference with head circumference. From the graph, it can be seen that there is a positive polynomial correlation between abdominal circumference and head circumference with a correlation of determination of $r^2 = 0.9996$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the quadratic regression equation $y = -0.0009x^2 + 1.3431x - 9.0021$ where y is the head circumference in millimeters and x is the abdominal circumference in millimeters. Fig.6. 53 shows relationship between femur length and abdominal circumference. There is a positive linear correlation between femur length and abdominal circumference with a correlation of determination of $r^2 = 0.9952$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the linear regression equation $y = 0.2381x – 5.0199$ where y is the femur length in millimeters and x is the abdominal circumference in millimeters.

Fig. 6.54 shows the relationship between fetal weight which is strongly correlated with fetal nutrition and abdominal circumference. From this graph, it can be seen that there is a positive polynomial correlation between fetal weight and abdominal circumference with a correlation of determination of $r^2 = 0.9982$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the second order regression equation $y = 0.065x^2 – 16.072x + 1355.5$ where y is the fetal weight in grams and x is the abdominal circumference in millimeters. Abdominal circumference centile values for 5^{th}, 50^{th} and 95^{th} centiles are plotted as shown in Fig. 6.55. In Fig. 6.56, 3rd, 50^{th}, and 97^{th} centiles are smoothened into a growth chart which can be utilized to determine growth of fetal abdominal circumference. Fig. 6.57 is a graphical display showing the growth rate of the measured fetal abdominal circumference. It is clear from this graph that growth rate fluctuates throughout the period of intrauterine life.

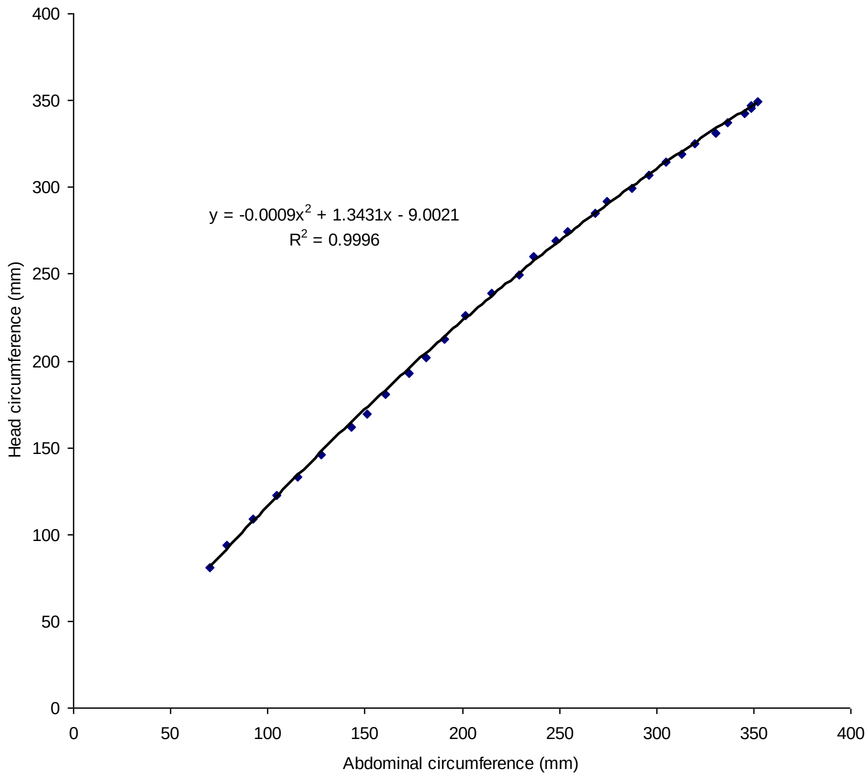

Fig. 6.52 *Correlation and regression equation of mean abdominal circumference values in 13,740 Nigerian fetuses in Jos plotted against abdominal circumference.*

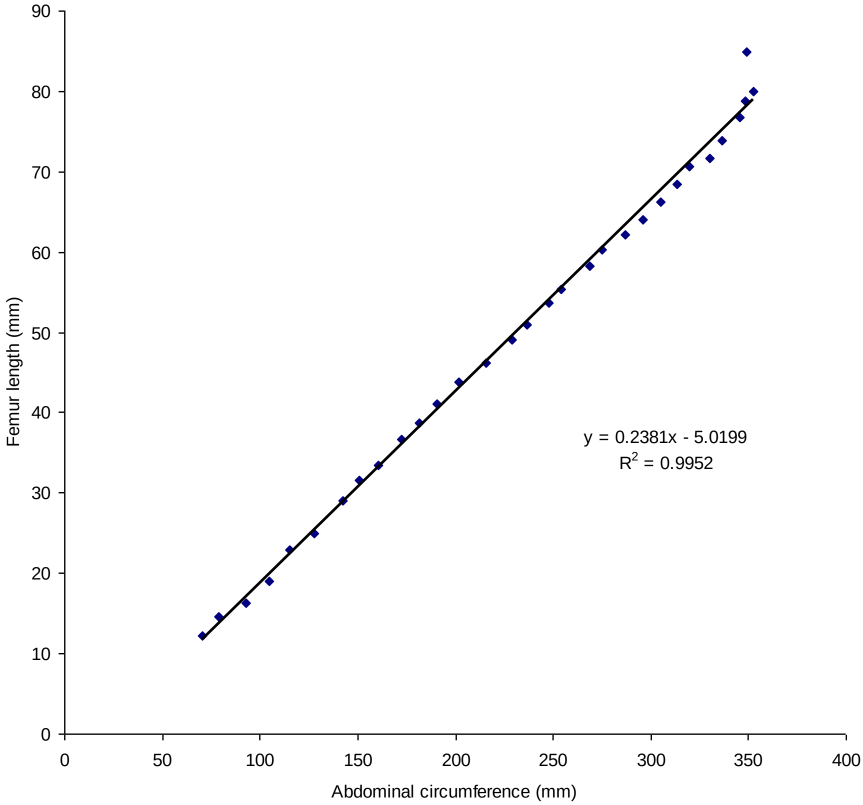

Fig. 6.53 *Correlation and regression equation of mean abdominal circumference values in 13,740 Nigerian fetuses in Jos plotted against femur length.*

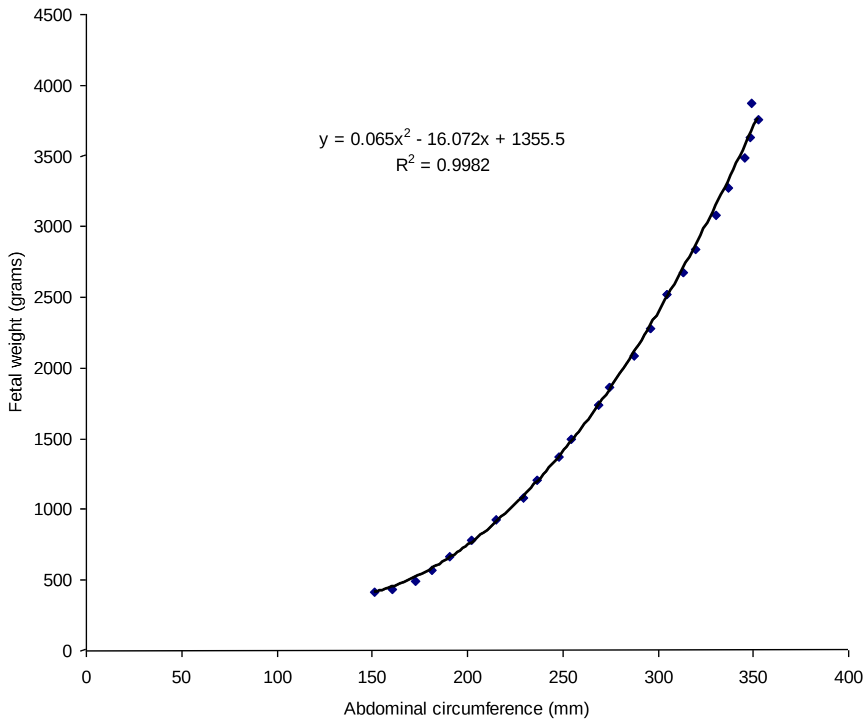

Fig. 6.54 *Correlation and regression equation of mean abdominal circumference values in 13,740 Nigerian fetuses in Jos plotted against fetal weight.*

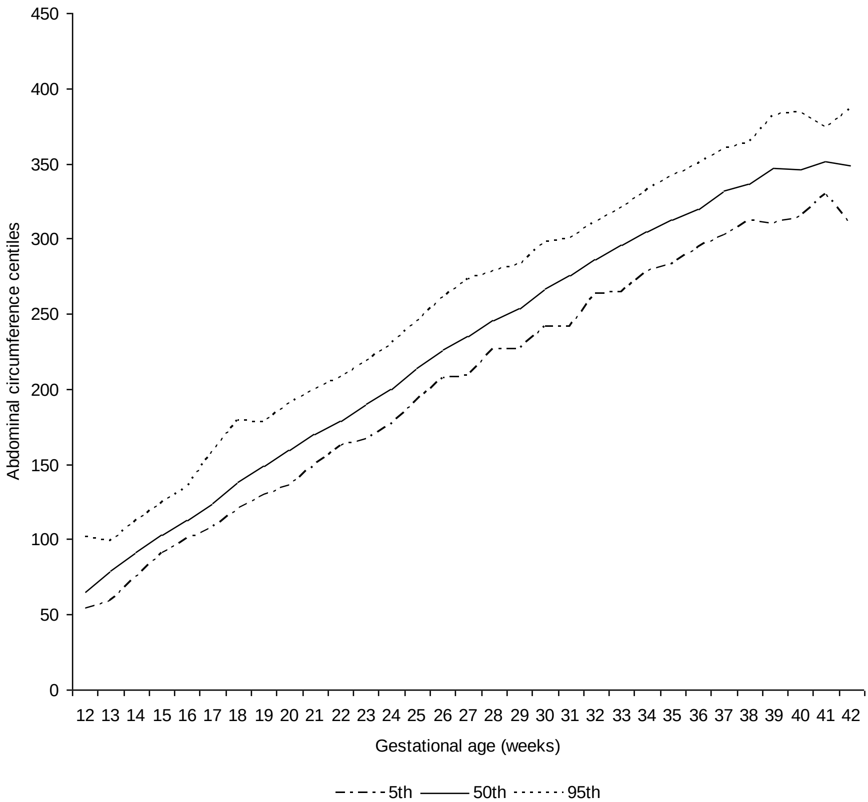

Fig. 6.55 *Fifth, 50th and 95th centiles for abdominal circumference in 13,740 fetuses at different gestational ages from 12 to 42 weeks.*

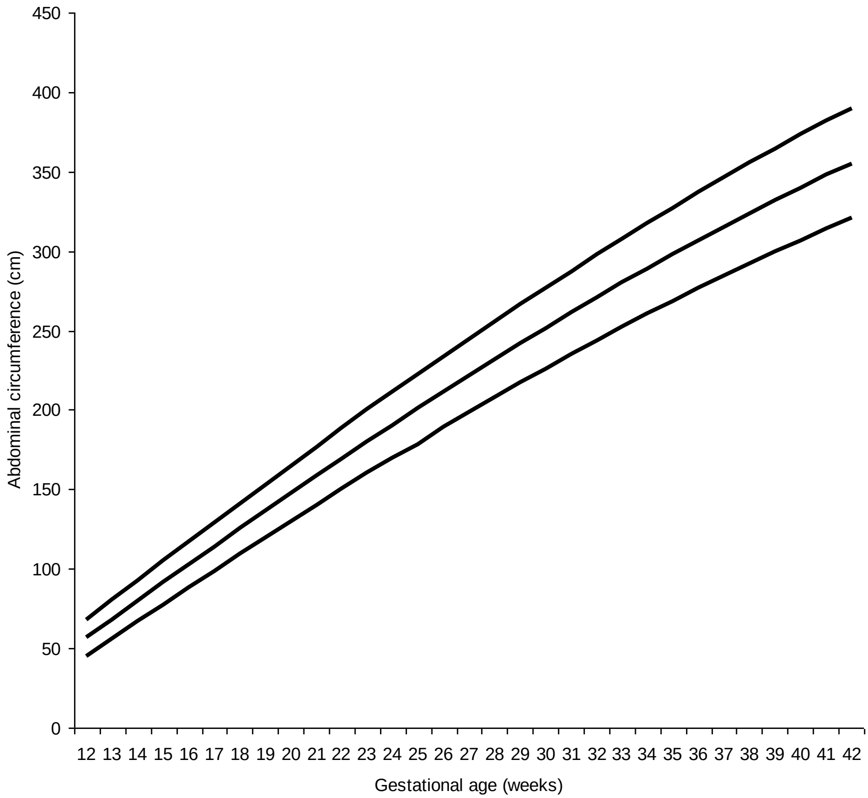

Fig. 6.56 *Curves created from 3rd, 50th and 97th fetal abdominal circumference centiles.*

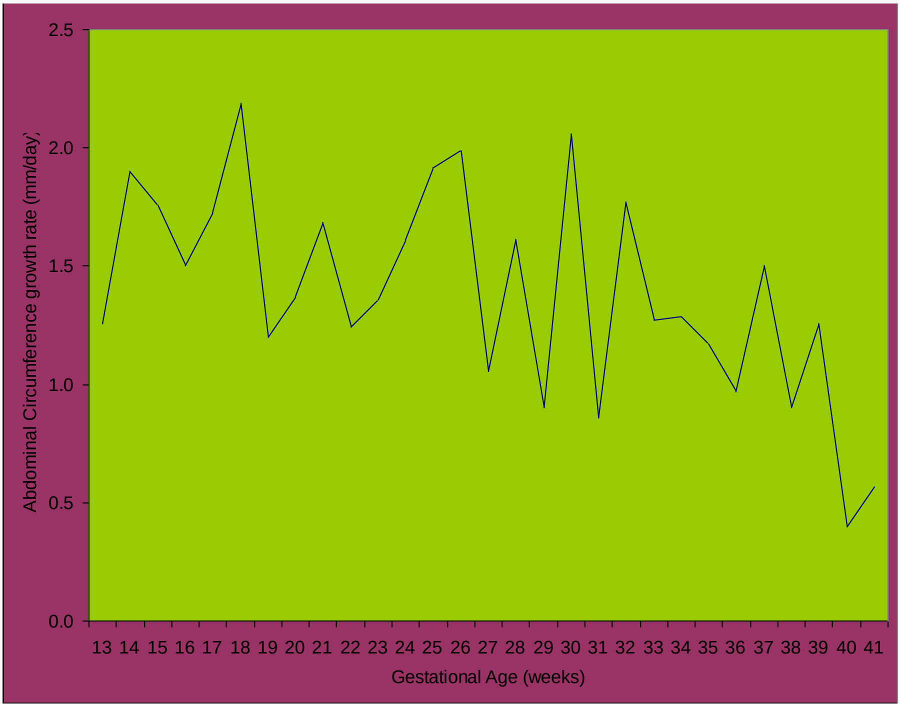

Fig. 6.57 *Growth velocity pattern of abdominal circumference in 13,740 Nigerian fetuses in Jos ranging from 12 – 42 weeks.*

Biometrics of Fetal Femur Length

Fetal femur length measurements were classified into thirty one groups. The mean values at each week of gestation from 12 – 42 are as shown in Tab. 6.17. This table gives the mean values of fetal femur length measurements for each gestational age in weeks from 12 – 42 weeks together with their corresponding standard deviations and standard errors of mean. Variability of measurements was marked at weeks 16, 18, 37, 38 and 41 with the highest at 16 weeks. The standard error is found to be less than 1 throughout the period of gestation except at 42 weeks where it is 2.6 millimeters. With the arithmetic mean, one has some idea of the kind of numbers it represents, but the whole story is still a mystery. To clear up the mystery of the hidden numbers that made up a mean, the standard deviation is necessary. For example, the mean femur length at 28 weeks is 53.6mm plus 3.4mm or 53.6mm minus 3.4mm. This means 2 out of 3 measurements of femur length at 28 weeks, approximately 365 femur length measurements in a class of 548, should be between 50.2mm and 57.0mm. Since the standard error of mean at 28 weeks is 0.1mm, it is telling us that the real mean femur length of fetuses in Jos at 28 weeks is probably between 53.5mm and 53.7mm (53.6mm plus or minus 0.1mm). It can also be seen that the standard error of mean for each week of gestation from 12 – 42 is very small suggesting that the sample mean is very close to the population mean. For example, at 33 weeks gestation, the mean fetal femur length was 64.1mm while the standard error of mean was 2.4. This means that the difference between the mean femur lengths of the sample of fetuses at 33 weeks is just 2.4mm different from that of the population of fetuses at 13 weeks gestation. The geometric means (Tab. 6.18) of all sets of measurements from 12 – 42 weeks are less than their arithmetic means but greater than their harmonic means indicating that all the values of fetal femur length measurements were not identical. Tab.6. 19 gives the centile values of fetal femur length measurements. This table gives the 3rd, 5th, 10th, 50th, 90th, 95th, and 97th centile values for fetal femur length measured at different gestational age ranging from 12 – 42 weeks. For example, it can be seen from the table that the 5th percentile of femur length at 26 to 26 + 6 weeks gestation is 44 millimeters. This means that 5% of the fetuses at 26 to 26 + 6 had a mean femur length less than 44 millimeters, while 95% had a mean femur length greater than 44 mm. The 90th percentile of femur length at 33 to 33 + 6 weeks is 65 millimeters.

Tab. 6.17 *Frequency distribution table of fetal femur length measurements showing the arithmetic mean, standard deviation and standard error of mean from 12 – 42 weeks gestation.*

GA (weeks, days)	Fetuses (n)	Mean FL (mm)	SD	SE
12 to 12+6	49	12.2	2.1	0.3
13 to 13+6	384	14.6	8	0.4
14 to 14+6	371	16.3	4.8	0.2
15 to 15+6	351	19.0	3.1	0.2
16 to 16+6	505	22.9	6.3	0.3
17 to 17+6	427	25.0	2.9	0.1
18 to 18+6	446	29.0	5.2	0.2
19 to 19+6	282	31.6	4.3	0.3
20 to 20+6	553	33.5	3.8	0.2
21 to 21+6	400	36.7	3.9	0.2
22 to 22+6	398	38.7	3.5	0.2
23 to 23+6	478	41.1	2.9	0.1
24 to 24+6	520	43.8	3	0.1
25 to 25+6	388	46.2	3.8	0.2
26 to 26+6	511	49.1	3.6	0.1
27 to 27+6	432	50.9	2.3	0.1
28 to 28+6	548	53.6	3.4	0.1
29 to 29+6	484	55.4	3.8	0.2
30 to 30+6	625	58.3	3.5	0.1
31 to 31+6	523	60.3	3.4	0.1
32 to 32+6	583	62.1	3.3	0.1
33 to 33+6	516	64.1	2.4	0.1
34 to 34+6	744	66.2	3.4	0.1
35 to 35+6	739	68.5	2.4	0
36 to 36+6	599	70.6	3.3	0.1
37 to 37+6	532	71.7	5.5	0.2
38 to 38+6	481	73.9	4.7	0.2
39 to 39+6	525	76.7	3	0.1
40 to 40+6	252	78.8	3.7	0.2
41 to 41+6	72	79.9	5.4	0.6
42 to 42+6	22	84.9	12	2.6
Total	13,740			

***Tab. 6.18** Frequency distribution table of fetal femur length measurements showing arithmetic mean, geometric mean and harmonic mean from 12 – 42 weeks gestation.*

GA (week, days)	Number of fetuses (n)	Arithmetic mean (mm)	Geometric mean (mm)	Harmonic mean (mm)
12 to 12+6	49	12.20408	12.04776	11.9039
13 to 13+6	384	14.64063	13.85937	13.48663
14 to 14+6	371	16.34232	15.98908	15.74245
15 to 15+6	351	19.0114	18.78066	18.55452
16 to 16+6	505	22.93465	22.45429	22.13357
17 to 17+6	427	24.97424	24.80889	24.64348
18 to 18+6	446	29.00897	28.66378	28.37964
19 to 19+6	282	31.59575	31.33629	31.08744
20 to 20+6	553	33.4991	33.29572	33.09573
21 to 21+6	400	36.7075	36.50051	36.28643
22 to 22+6	398	38.72613	38.56079	38.38766
23 to 23+6	478	41.14675	41.04465	40.94054
24 to 24+6	520	43.77735	43.66936	43.5484
25 to 25+6	388	46.18299	46.00735	45.79766
26 to 26+6	511	49.08806	48.96292	48.84365
27 to 27+6	432	50.90278	50.84937	50.79458
28 to 28+6	548	53.55109	53.44577	53.34311
29 to 29+6	484	55.42355	55.26376	55.05746
30 to 30+6	625	58.2512	58.15721	58.06916
31 to 31+6	523	60.25813	60.16758	60.08173
32 to 32+6	583	62.0566	61.96439	61.86463
33 to 33+6	516	64.1376	64.08805	64.03426
34 to 34+6	744	64.1376	64.08805	64.03426
35 to 35+6	739	68.51151	68.47121	68.43069
36 to 36+6	599	70.5793	70.50031	70.41488
37 to 37+6	532	71.7124	71.26648	69.96014
38 to 38+6	481	73.88982	73.64711	73.19981
39 to 39+6	525	76.70477	76.64517	76.58453
40 to 40+6	252	78.78175	78.69141	78.59788
41 to 41+6	72	79.93056	79.76249	79.60353
42 to 42+6	22	84.90909	84.10523	83.32234
Total	13,740			

Tab. 6.19 *Fetal femur length centiles from 12 – 42 weeks.*

Femur Length percentiles (mm)							
GA (weeks, days	**3rd**	**5th**	**10th**	**50th**	**90th**	**95th**	**97th**
12 to 12+6	9.0	9.5	10.0	12.0	14.0	17.0	19.0
13 to 13+6	10.0	10.0	11.0	14.0	16.0	18.0	20.5
14 to 14+6	12.0	12.0	13.0	16.0	19.0	21.0	21.0
15 to 15+6	13.6	14.0	16.0	19.0	22.0	23.4	24.0
16 to 16+6	17.0	18.0	19.0	22.0	26.0	27.0	28.0
17 to 17+6	20.0	20.0	21.0	25.0	27.0	30.0	31.0
18 to 18+6	22.0	23.0	25.0	29.0	31.0	33.0	37.0
19 to 19+6	26.0	27.0	28.0	31.0	36.0	37.8	42.6
20 to 20+6	26.6	27.0	29.0	34.0	38.0	39.0	40.0
21 to 21+6	29.0	30.0	32.0	37.0	40.0	41.0	42.0
22 to 22+6	30.0	32.0	34.0	39.0	42.0	43.0	44.0
23 to 23+6	35.0	36.0	37.0	42.0	44.0	46.0	46.0
24 to 24+6	38.0	39.0	40.0	44.0	47.0	48.0	49.0
25 to 25+6	39.7	41.0	42.9	46.0	49.0	52.0	53.0
26 to 26+6	42.0	44.0	46.0	49.0	52.8	55.0	56.0
27 to 27+6	46.0	47.0	48.3	51.0	54.0	54.4	55.0
28 to 28+6	48.0	49.0	50.0	54.0	57.0	58.0	59.0
29 to 29+6	50.0	51.0	52.5	55.0	59.0	61.0	62.0
30 to 30+6	52.0	53.3	56.0	58.0	61.0	63.0	65.0
31 to 31+6	55.0	55.0	57.0	60.0	62.0	64.0	66.0
32 to 32+6	56.0	57.0	59.0	62.0	64.0	65.0	66.0
33 to 33+6	59.0	60.0	62.0	64.0	65.0	66.0	67.0
34 to 34+6	60.0	62.0	64.0	66.5	68.0	69.0	70.0
35 to 35+6	63.0	65.0	66.0	69.0	70.0	70.0	72.0
36 to 36+6	65.0	66.0	68.0	71.0	72.0	72.0	73.0
37 to 37+6	64.0	65.0	69.0	73.0	74.0	74.0	75.0
38 to 38+6	66.0	69.0	71.0	75.0	76.0	76.0	77.0
39 to 39+6	70.0	71.3	73.0	77.0	79.0	80.0	81.0
40 to 40+6	69.7	72.0	74.0	80.0	83.0	83.4	84.4
41 to 41+6	73.0	73.0	74.3	79.0	88.0	92.0	96.9
42 to 42+6	71.0	71.0	71.6	81.0	99.0	99.0	99.0

Hence 90% of fetuses at 33 to 33 + 6 weeks had a mean femur length less than 65 millimeters while 10% had a mean femur length greater than 65 millimeters.

The standard score or z-score of femur length measurements in 13,740 fetuses ranging from 12 – 42 weeks of gestation is shown in Tab. 6.33. The z-score enables one to look at femur length measurements at each gestational age and see how they compare on the same standard; taking into account the mean and standard deviation of each gestational age. For example, femur length measurements at 20 weeks are 0.0000 standard deviations from the mean while measurements at 36 weeks are – 0.0014 standard deviations from the mean. Again, from the above z-score table, it can be seen that the femur length measurements at 38 weeks gestation are – 0.00067 standard deviations from the mean**.** When femur length data of 13,740 fetuses was subjected to skewness analysis at different gestational age ranging from 12 – 42 weeks (Fig. 6.58), it can be seen that the distribution of femur length measurements has a longer "tail" to the right of the central maximum than to the left or is skewed to the right from 13 – 21weeks and then at 26, 28, 30, 31, 32, 35, and 41weeks. From 22 – 25weeks and then at 27, 29, 33, 34, 36, 37, 38, 39 and 40weeks, the distribution has a longer "tail" to the left of the central maximum than to the right or is skewed to the left. By the time pregnancy reaches term, the distribution becomes skewed to the right before skewing again to the left as from 41 weeks. When the femur length data was subjected to kurtosis analysis (Fig. 6.59), the distribution was found to be leptokurtic at 13, 14, 16, 37 and 38 weeks of gestation while at other weeks of gestation, the distribution was mesokurtic. The coefficient of dispersion of femur length data of 13,740 fetuses at different gestational age shows a decrease in value as gestational age advances except at term where it peaks (Fig. 6.60). The femur length scattergram in Fig. 6.61 shows that there are very few bad data points or outliers in the femur length measurements of 13,740 fetuses. The outliers are more from 26 – 42 weeks of gestation. In Fig. 6.62, mean femur length is plotted against gestational age with error bars showing standard deviation. Arithmetic mean and standard deviation go together like star and satellite. With the mean, we have some idea of the kind of numbers it represents, but the whole story is still a mystery. To clear up the mystery of the hidden numbers that made up a mean, the standard deviation is necessary.

Tab. 6.20 *Standard score (z-score) of femur length measurements in 13,740 Nigerian fetuses in Jos ranging from 12 – 42 weeks gestation.*

GA (weeks, days)	Fetuses (n)	Mean z-score
12 to 12+6	49	3.89E-04
13 to 13+6	384	4.23E-03
14 to 14+6	371	3.59E-03
15 to 15+6	351	8.26E-04
16 to 16+6	505	3.57E-03
17 to 17+6	427	-2.36E-03
18 to 18+6	446	3.82E-04
19 to 19+6	282	-2.80E-04
20 to 20+6	553	-7.12E-05
21 to 21+6	400	6.41E-04
22 to 22+6	398	2.31E-03
23 to 23+6	478	3.49E-03
24 to 24+6	520	-1.45E-03
25 to 25+6	388	-1.22E-03
26 to 26+6	511	-7.85E-04
27 to 27+6	432	1.80E-04
28 to 28+6	548	-3.68E-03
29 to 29+6	484	1.01E-03
30 to 30+6	625	-2.87E-03
31 to 31+6	523	-2.81E-03
32 to 32+6	583	-2.95E-03
33 to 33+6	516	2.91E-03
34 to 34+6	744	2.44E-03
35 to 35+6	739	8.52E-04
36 to 36+6	599	-1.41E-03
37 to 37+6	532	9.06E-04
38 to 38+6	481	-6.75E-04
39 to 39+6	525	3.31E-04
40 to 40+6	252	-1.29E-03
41 to 41+6	72	2.59E-03
42 to 42+6	22	3.90E-04
Total	13,740	

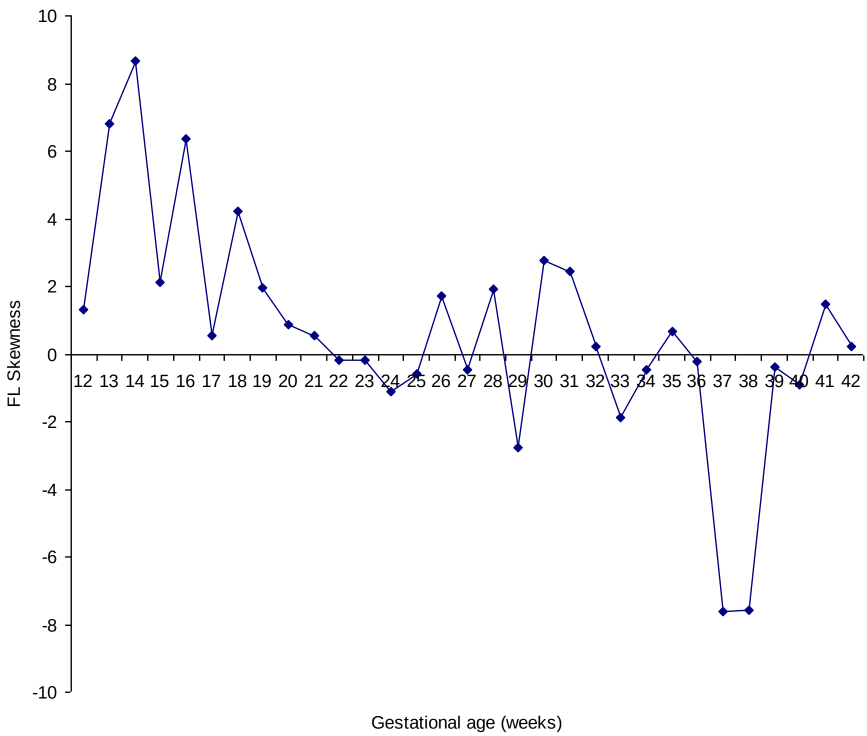

Fig. 6.58 *Femur length data of 13,740 fetuses subjected to Skewness analysis at different gestational age ranging from 12 – 42 weeks.*

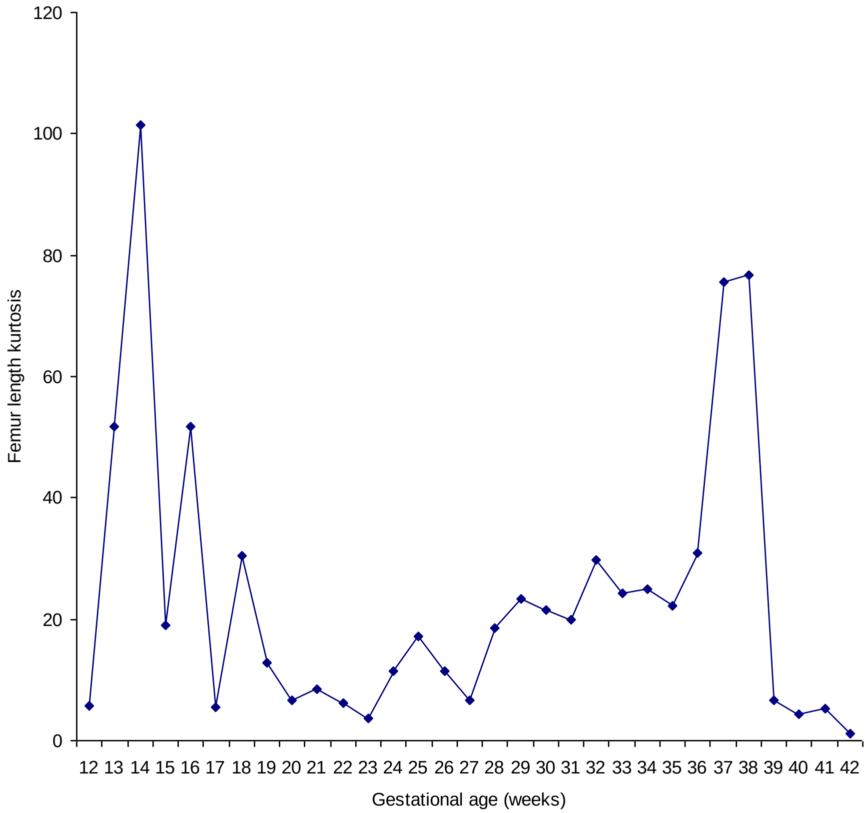

Fig. 6.59 *Femur length data of 13,740 fetuses subjected to kurtosis analysis at different gestational age ranging from 12 – 42 weeks.*

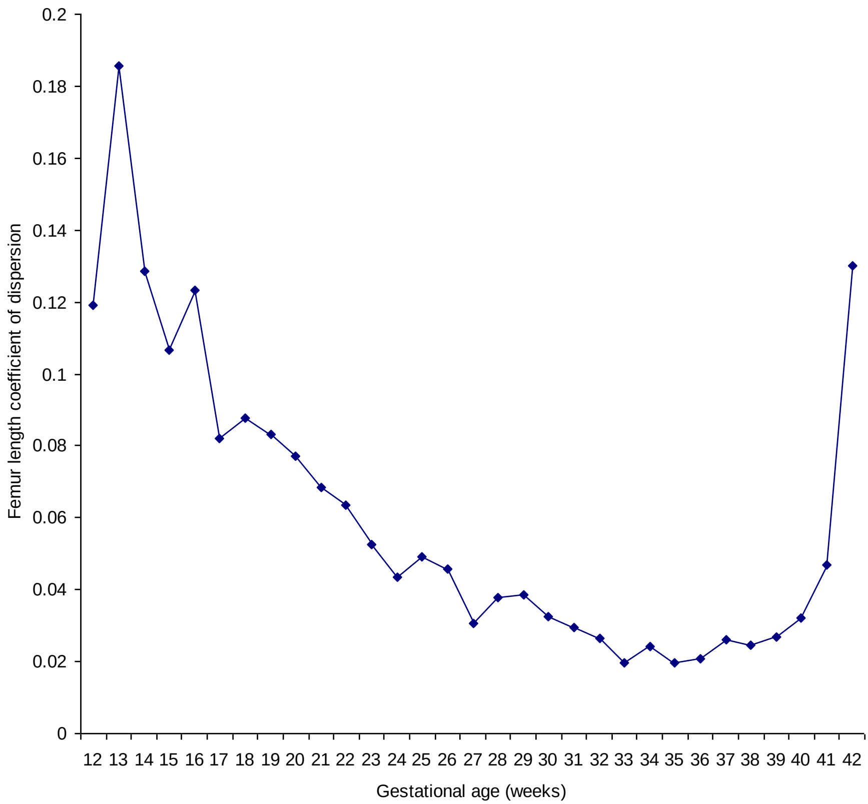

Fig. 6.60 *Femur length coefficient of dispersion in 13,740 fetuses of gestational ages between 12 to 42 weeks.*

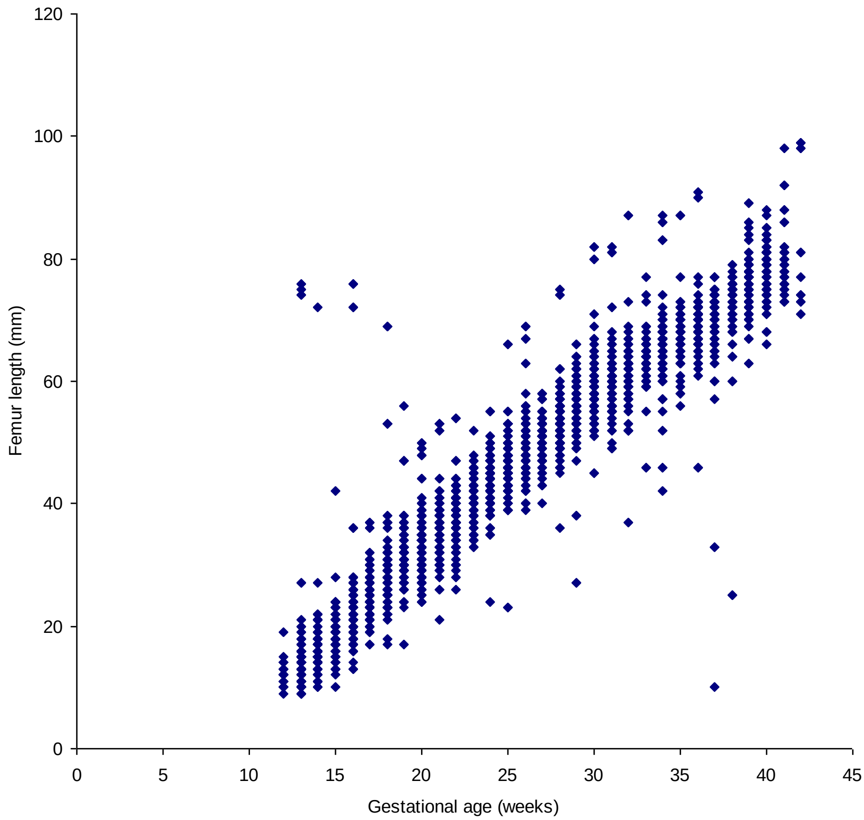

Fig. 6.61 *Scattergram of 13,740 fetal femur length measurements from 12 – 42 weeks gestation.*

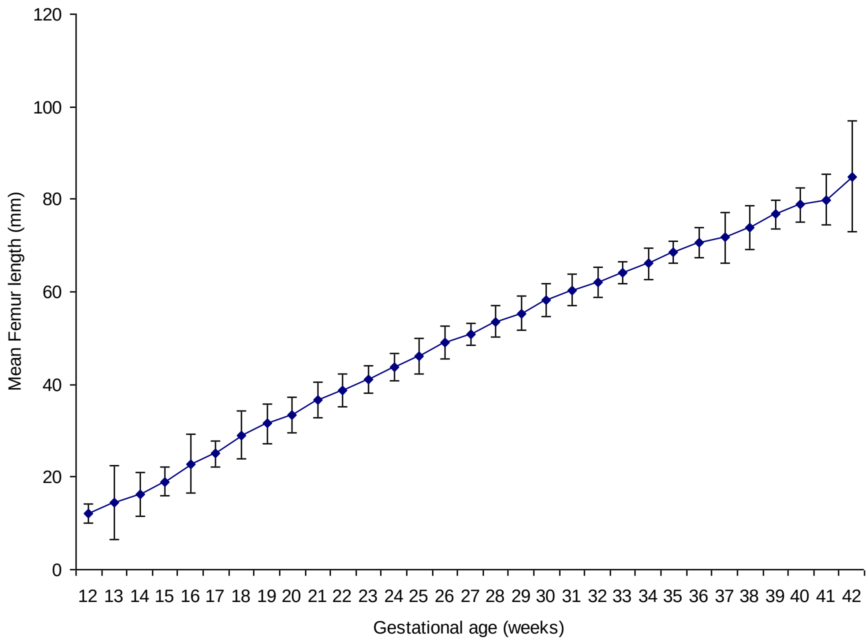

Fig. 6.62 *Mean fetal femur length values in 13,740 fetuses of women at different gestational ages between 12 – 42 weeks. The vertical bars show the values of ± SD.*

For example, the mean ± 1 standard deviation will include about 2 out of 3 numbers in the group while the mean ± 2 standard deviations will include about 95 out of 100 numbers in the group and the mean ± 3 standard deviations will include 997 numbers out of 1,000. Mathematical modeling of data demonstrated that the best-fitted regression model (Fig. 6.63) to describe the relationship between femur length and gestational age was the second order polynomial regression equation $y = -0.017x^2 + 3.2794x - 25.282$ with a correlation of determination of $r^2 = 0.999$ ($P < 0.0001$) where y is the femur length in millimeters and x is the gestational age in weeks. When monthly mean values of femur length are plotted against gestational age in months, a positive polynomial correlation between gestational age and femur length with a correlation of determination of $r^2 = 0.9992$ ($P < 0.0001$) in Nigerian fetuses in Jos was found

(Fig. 6.64). The relationship is best described by the second order polynomial regression equation $y = -3.667x^2 + 15.462x - 38.6$ where y is the femur length in millimeters and x is the gestational age in months.

When other fetal anthropometric parameters like head circumference, biparietal diameter, occipitofrontal diameter, abdominal circumference and weight are plotted against femur length certain hidden relationships can be forced out. For example, Fig. 6.65 shows the relationship of femur length with biparietal diameter. From the graph, it can be seen that there is a positive polynomial correlation between femur length and biparietal diameter with a correlation of determination of $r^2 = 0.9993$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the fourth order polynomial regression equation $y = -4E\text{-}06x^4 + 0.0006x^3 - 0.0414x^2 + 2.3555x - 1.7905$ where y is the biparietal diameter in millimeters and x is the femur length in millimeters. Fig.6. 66 shows relationship of femur length with occipitofrontal diameter. There is a positive polynomial correlation between femur length and biparietal diameter. The relationship is best described by the quadratic regression equation of $y = -0.007x^2 + 2.0251x + 4.2448$ with a correlation of determination of $r^2 = 0.9973$ ($P < 0.0001$) in Nigerian fetuses in Jos. Fig. 6.67 shows relationship of femur length with abdominal circumference.

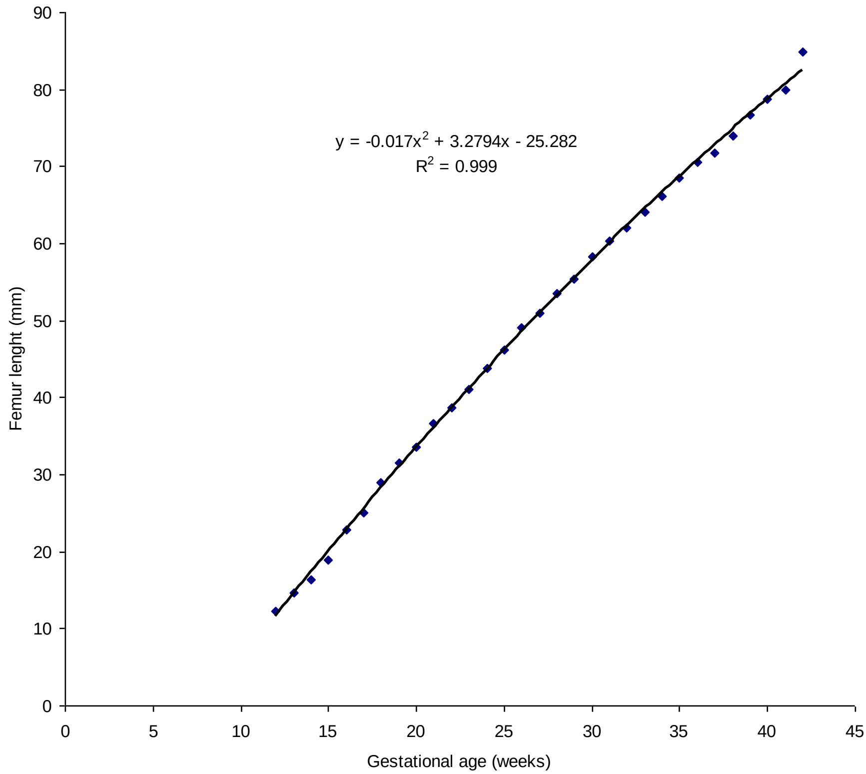

Fig. 6.63 *Correlation and regression equation of mean femur length values in 13,740 Nigerian fetuses in Jos plotted against gestational age in weeks.*

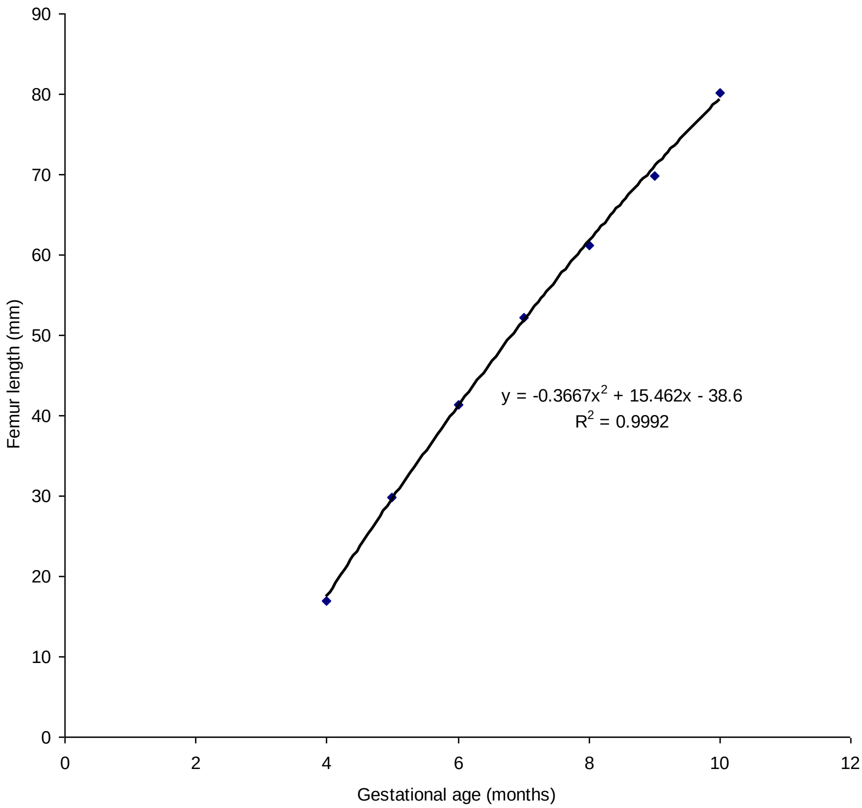

Fig. 6.64 *Correlation and regression equation of mean femur length values in 13,740 Nigerian fetuses in Jos plotted against gestational age in months.*

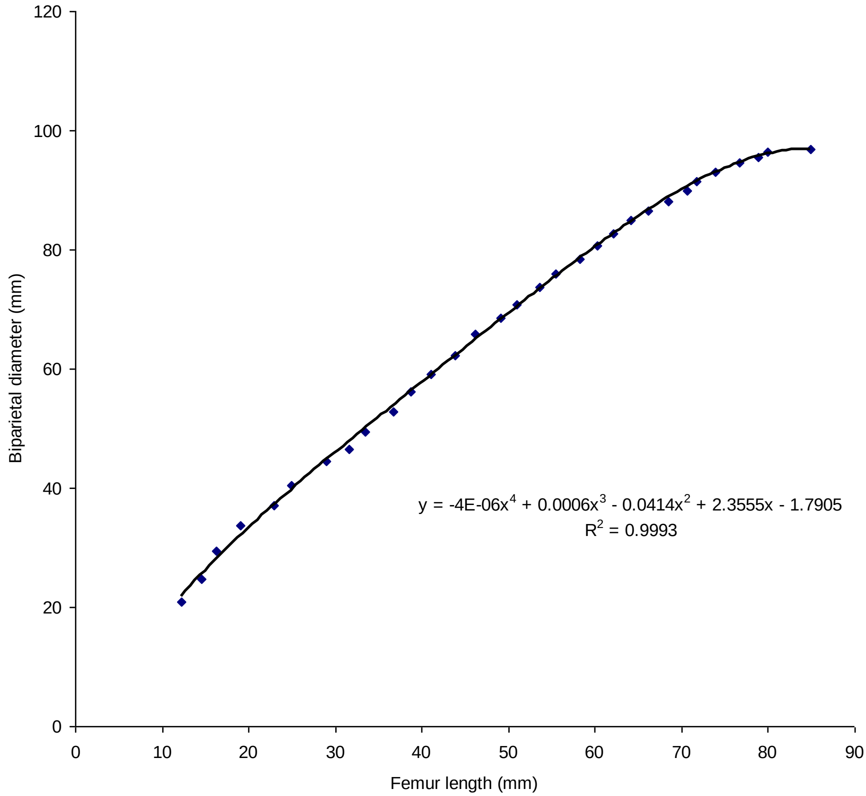

Fig. 6.65 *Correlation and regression equation of mean femur length values in 13,740 Nigerian fetuses in Jos plotted against biparietal diameter.*

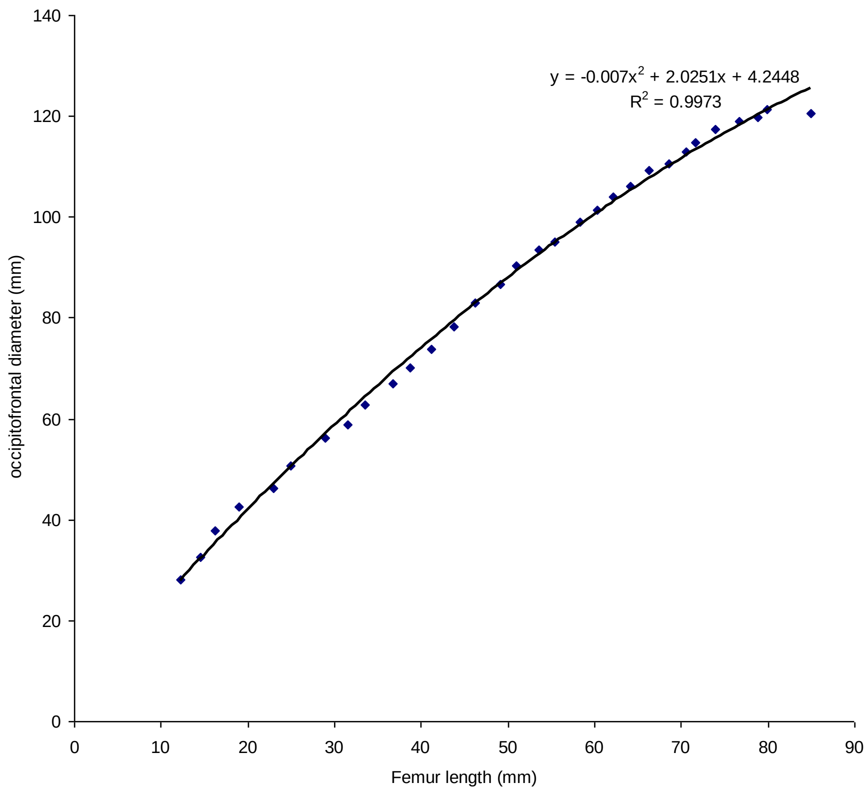

Fig. 6.66 *Correlation and regression equation of mean femur length values in 13,740 Nigerian fetuses in Jos plotted against occipitofrontal diameter.*

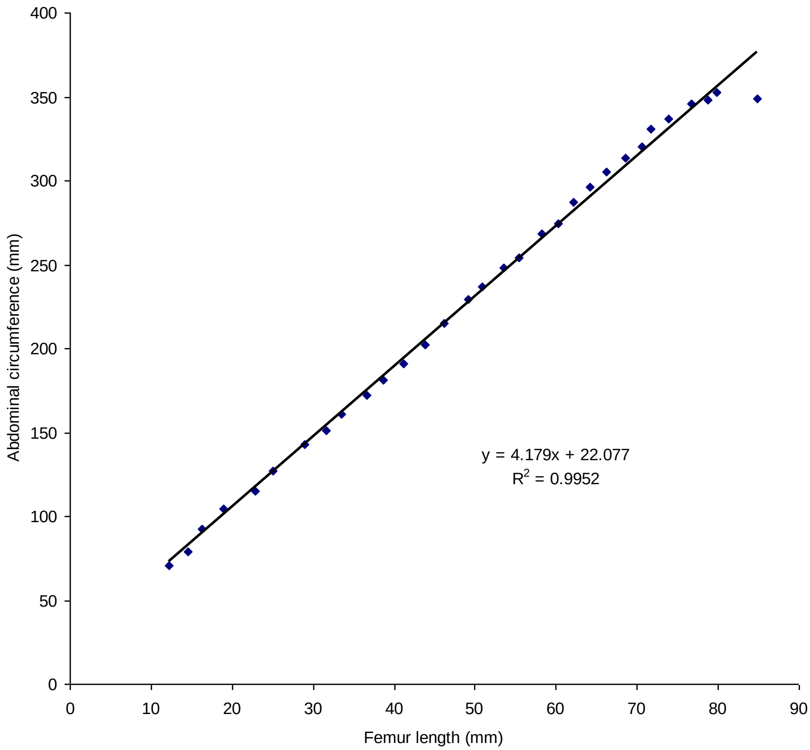

Fig. 6.67 *Correlation and regression equation of mean femur length values in 13,740 Nigerian fetuses in Jos plotted against femur length.*

From the graph, it can be seen that there is a positive linear correlation between femur length and femur length with a correlation of determination of $r^2 = 0.9952$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the linear regression equation $y = 4.179x + 22.077$ where y is the abdominal circumference in millimeters and x is the femur length in millimeters. Fig. 6.68 shows relationship between femur length and head circumference. There is a positive polynomial correlation between femur length and head circumference with a correlation of determination of $r^2 = 0.9989$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the third order regression equation $y = -0.0004x^3 + 0.0429x^2 + 3.1567x + 43.238$ where y is the head circumference in millimeters and x is the femur length in millimeters. Fig. 6.69 shows the relationship between fetal weight which is strongly correlated with fetal nutrition and femur length. From the graph, it can be seen that there is a positive power correlation between fetal weight and femur length with a correlation of determination of $r^2 = 0.9944$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the power regression equation $y = 0.0575x^{2.534}$ where y is the fetal weight in grams and x is the femur length in millimeters. Femur length centiles values for 5th, 50th and 95th centiles are plotted as shown in Fig. 6.70. In Fig. 6.71, the 5th, 50th and 95th centiles are smoothened into a growth chart which can be utilized to determine growth of fetus using femur length. Fig. 6.72 is a graphical display showing the growth rate of the measured fetal femur length during intrauterine life.

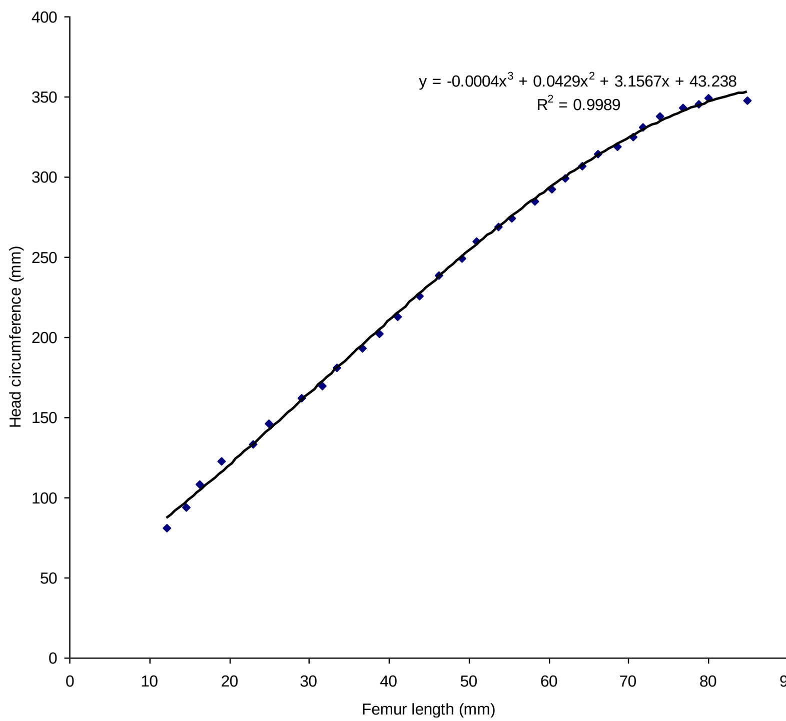

Fig. 6.68 *Correlation and regression equation of mean femur length values in 13,740 Nigerian fetuses in Jos plotted against femur length.*

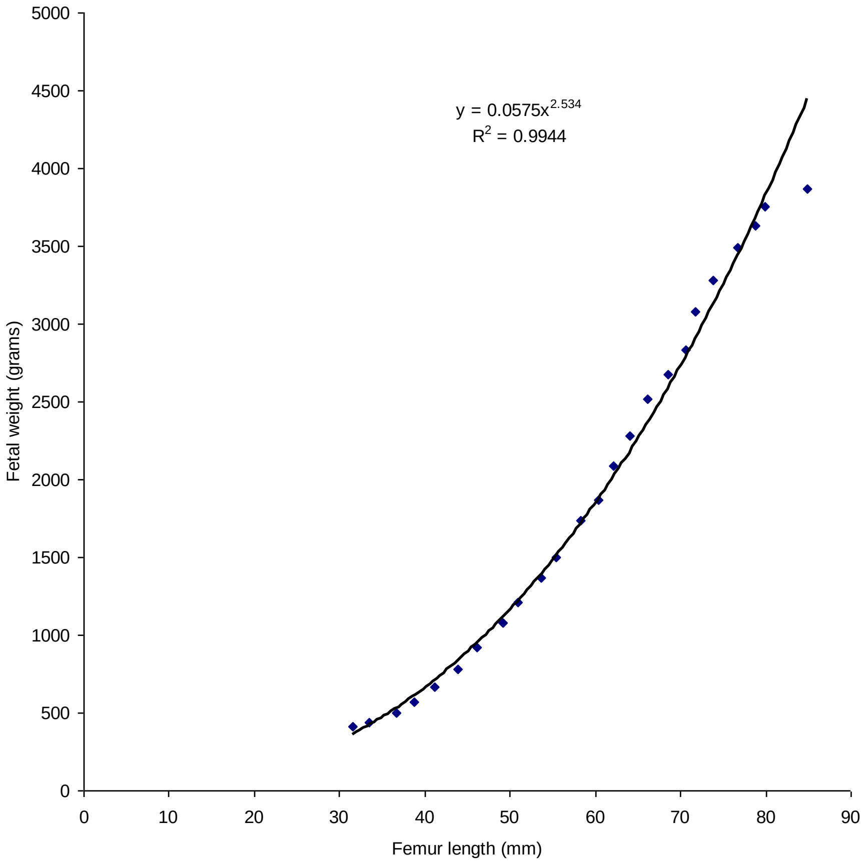

Fig. 6.69 *Correlation and regression equation of mean femur length values in 13,740 Nigerian fetuses in Jos plotted against fetal weight.*

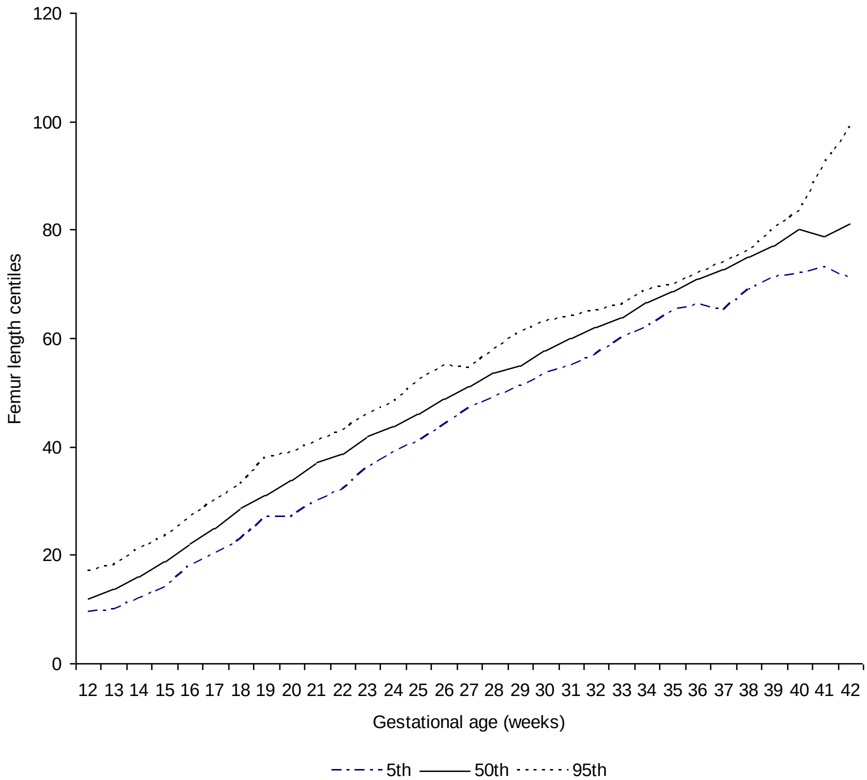

Fig. 6.70 *Fifth, 50th and 95th centiles for femur length in 13,740 fetuses at different gestational ages from 12 to 42 weeks.*

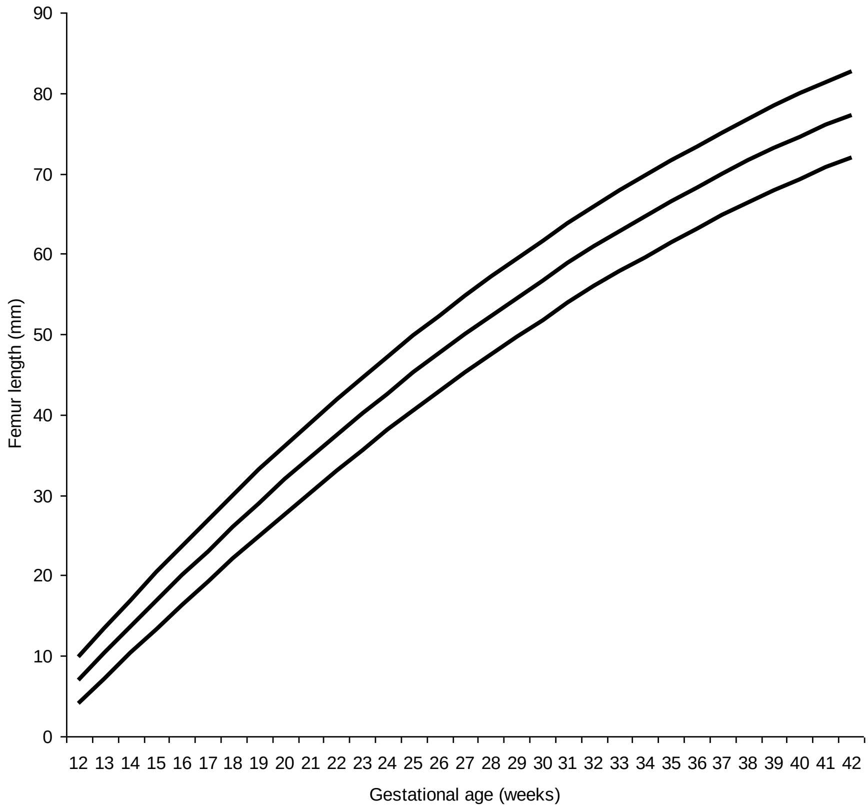

Fig. 6.71 *Curves created from 3rd, 50th and 97th fetal femur length centiles.*

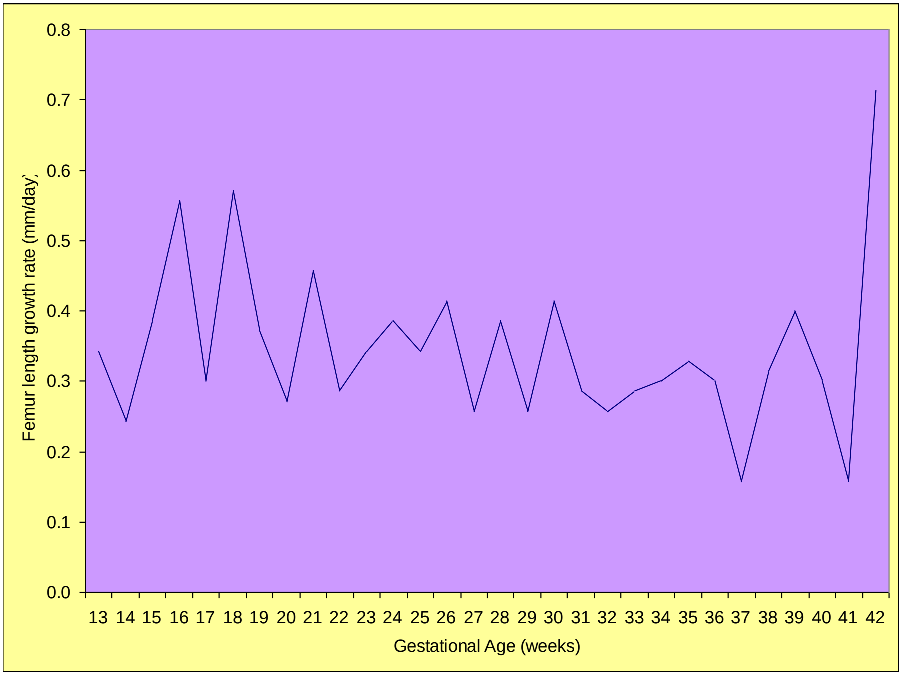

Fig. 6.72 *Growth velocity pattern of femur length in 13,740 Nigerian fetuses in Jos ranging from 12 – 42 weeks.*

Biometrics of Fetal Weight

The fetal weight measurements were classified into twenty six groups. The mean weight values at each week of gestation from 17 – 42 are as shown in Tab. 6.21. This table gives the mean values of fetal weight measurements for each gestational age in weeks from 17 – 42 weeks together with their corresponding standard deviations and standard errors of mean. The standard deviation is necessary to clear up the mystery of the hidden numbers that made up a mean. For example, the mean weight at 39 weeks is 3490.8g plus 360.3g or 3490.8g minus 360.3g. This means 2 out of 3 measurements of weight at 39 weeks, approximately 350 weight measurements in a class of 525, should be between

3130.5g and 3851.1g. Since the standard error of mean at 39 weeks is 15.8g, it is telling us that the real mean weight of fetuses in Jos at 39 weeks is probably between 3475.0g and 3506.6g (3490.8g plus or minus 15.8g). The variability of the fetal weight measurements increases as gestational age increases. However, at week 18, there is marked variation up to 650 grams.

The geometric means (Tab. 6.22) of all sets of measurements from 17 – 42 weeks are less than their arithmetic means but greater than their harmonic means indicating that all the values of fetal weight measurements were not identical. Tab.6. 23 gives the 3rd, 5th, 10th, 50th, 90th, 95th, and 97th centile values for fetal weight measured at different gestational age ranging from 17 – 42 weeks. For example, it can be seen from the table that the 10th percentile of fetal weight at 20 to 20 + 6 weeks gestation is 300 grams. This means that 10% of the fetuses at 20 to 20 + 6 had a mean fetal weight less than 300 grams, while 90% had a mean fetal weight greater than 300 grams. Similarly, the 97th percentile of fetal weight at 36 to 36 + 6 is 3200 grams. Hence 97% of fetuses at 36 to 36 + 6 had a mean fetal weight less than 3200 grams while 3% had a mean fetal weight greater than 3200 grams.

When weight data of 12,080 fetuses was subjected to skewness analysis at different gestational age ranging from 17 – 42 weeks (Fig. 6.73), it can be seen that the distribution of weight measurements has a longer “tail” to the right of the central maximum than to the left or is skewed to the right from 17 – 31 weeks; and then later at 35, 39, 40 and 41 weeks. From 32, 33, 34, 36, 37, 38 and 42 weeks, the distribution has a longer “tail” to the left of the central maximum than to the right or is skewed to the left.

Tab. 6.21 *Frequency distribution table of fetal weight measurements showing the arithmetic mean, standard deviation and standard error of mean from 12 – 42 weeks gestation.*

GA (week, days)	Fetuses (n)	weight (g)	SD	SEM
17 to 17+6	427	319.0	40.2	8.8
18 to 18+6	446	731.9	650.8	94.9
19 to 19+6	282	413.3	101.8	11.8
20 to 20+6	553	437.6	81.0	4.4
21 to 21+6	400	496.3	73.2	3.9
22 to 22+6	398	567.4	124.5	6.5
23 to 23+6	478	668.4	180.9	8.5
24 to 24+6	520	781.9	161.7	7.2
25 to 25+6	388	925.0	177.6	9.1
26 to 26+6	511	1077.6	217.9	9.7
27 to 27+6	432	1206.8	226.8	11.0
28 to 28+6	548	1370.2	227.7	9.8
29 to 29+6	484	1498.1	204.2	9.4
30 to 30+6	625	1733.8	297.7	12.0
31 to 31+6	523	1865.1	295.3	13.0
32 to 32+6	583	2086.1	276.3	11.5
33 to 33+6	516	2279.6	298.8	13.2
34 to 34+6	744	2516.0	333.0	12.4
35 to 35+6	739	2675.0	352.8	13.0
36 to 36+6	599	2837.0	341.3	14.1
37 to 37+6	532	3079.8	392.0	17.2
38 to 38+6	481	3276.7	351.3	16.2
39 to 39+6	525	3490.8	360.3	15.8
40 to 40+6	252	3634.9	419.8	26.4
41 to 41+6	72	3752.9	350.9	41.9
42 to 42+6	22	3868.2	599.5	127.8
Total	12,080			

***Tab. 6.22** Frequency distribution table of fetal weight measurements showing arithmetic mean, geometric mean and harmonic mean from 17 – 42 weeks gestation.*

GA (week, days)	Number of fetuses (n)	Arithmetic mean (mm)	Geometric mean (mm)	Harmonic mean (mm)
17 to 17+6	427	319.0476	316.8977	315
18 to 18+6	446	731.9149	544.7203	447.3412
19 to 19+6	282	413.3333	406.0622	401.4273
20 to 20+6	553	437.574	431.6011	426.7036
21 to 21+6	400	496.3173	491.1159	485.939
22 to 22+6	398	567.3854	559.6849	554.3026
23 to 23+6	478	668.3516	654.8652	645.9038
24 to 24+6	520	781.8898	769.4403	759.0261
25 to 25+6	388	925.0000	911.0558	897.5364
26 to 26+6	511	1077.624	1061.000	1046.67
27 to 27+6	432	1206.792	1187.759	1169.68
28 to 28+6	548	1370.24	1353.363	1336.422
29 to 29+6	484	1498.105	1484.898	1472.064
30 to 30+6	625	1733.764	1710.785	1688.828
31 to 31+6	523	1865.125	1841.298	1815.473
32 to 32+6	583	2086.066	2065.578	2039.616
33 to 33+6	516	2279.648	2256.348	2225.095
34 to 34+6	744	2515.978	2490.586	2457.018
35 to 35+6	739	2674.966	2651.654	2627.941
36 to 36+6	599	2836.974	2813.571	2785.043
37 to 37+6	532	3079.808	3039.085	2949.43
38 to 38+6	481	3276.744	3255.992	3231.927
39 to 39+6	525	3490.822	3472.1	3453.111
40 to 40+6	252	3634.921	3611.771	3589.447
41 to 41+6	72	3752.857	3736.914	3721.155
42 to 42+6	22	3868.182	3822.286	3775.203
Total	12080			

Tab. 6.23 *Frequency distribution table of fetal weight measurements showing arithmetic mean, geometric mean and harmonic mean from 17 – 42 weeks gestation.*

GA (week, days)	Number of fetuses (n)	Arithmetic mean (mm)	Geometric mean (mm)	Harmonic mean (mm)
17 to 17+6	427	319.0476	316.8977	315
18 to 18+6	446	731.9149	544.7203	447.3412
19 to 19+6	282	413.3333	406.0622	401.4273
20 to 20+6	553	437.574	431.6011	426.7036
21 to 21+6	400	496.3173	491.1159	485.939
22 to 22+6	398	567.3854	559.6849	554.3026
23 to 23+6	478	668.3516	654.8652	645.9038
24 to 24+6	520	781.8898	769.4403	759.0261
25 to 25+6	388	925.0000	911.0558	897.5364
26 to 26+6	511	1077.624	1061.000	1046.67
27 to 27+6	432	1206.792	1187.759	1169.68
28 to 28+6	548	1370.24	1353.363	1336.422
29 to 29+6	484	1498.105	1484.898	1472.064
30 to 30+6	625	1733.764	1710.785	1688.828
31 to 31+6	523	1865.125	1841.298	1815.473
32 to 32+6	583	2086.066	2065.578	2039.616
33 to 33+6	516	2279.648	2256.348	2225.095
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41 to 41+6	72	3752.857	3736.914	3721.155
42 to 42+6	22	3868.182	3822.286	3775.203
Total	12080			

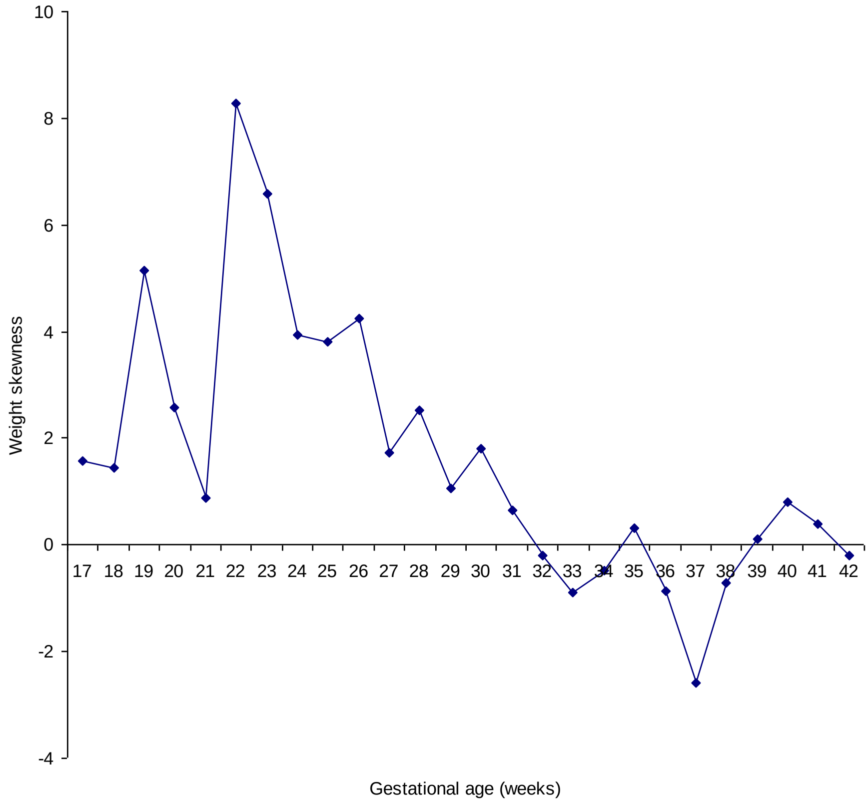

Fig. 6.73 *Weight data of 12,080 fetuses subjected to Skewness analysis at different gestational age ranging from 12 – 42 weeks.*

When the weight data was subjected to kurtosis analysis (Fig. 6.74), the analysis was found to be leptokurtic at 19, 22, 23, 24, 25, 26, 28 and 37 weeks of gestation while at the other gestational ages, the distribution was found to be was mesokurtic. The coefficient of dispersion of weight data of 12,080 fetuses at different gestational age shows a decrease in value as gestational age advances except at 18 weeks where it peaks (Fig. 6.75). In Fig. 6.76, mean weight is plotted against gestational age with error bars showing standard deviation. Mathematical modeling of data demonstrated that the best-fitted regression model (Fig. 6.77) to describe the relationship between weight and gestational age was the power regression equation $y = 0.038x^{3.1347}$ where y is the fetal weight in grams and x is the fetal age in weeks with a correlation of determination of $r^2 = 0.9951$ ($P< 0.0001$) in Nigerian fetuses in Jos.

When other fetal anthropometric parameters like head circumference, biparietal diameter, occipitofrontal diameter, abdominal circumference and femur length are plotted against weight, certain hidden relationships can be forced out. For example, Fig. 6.78 shows the relationship of weight with head circumference. From the graph, it can be seen that there is a positive polynomial correlation between head circumference and weight with a correlation of determination of $r^2 = 0.9997$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the fourth order polynomial regression equation $y = 3E\text{-}12x^4 + 3E\text{-}08x^3 – 0.0001x^2 + 0.2173x + 106.44$ where y is the head circumference and x is the fetal weight in grams. Fig. 6.79 shows the relationship of fetal weight with occipitofrontal diameter which has regression equation of $y = – 9E\text{-}13x^4 + 1E\text{-}08x^3 – 4E\text{-}05x^2 + 0.0779x + 36.004$ where y is occipitofrontal diameter and x is the fetal weight in grams with a correlation of determination of $r^2 = 0.9992$ ($P < 0.0001$) in Nigerian fetuses in Jos. Fig. 6.80 shows the relationship between biparietal diameter and weight. The relationship is best described by the fourth order polynomial regression equation $y = – 3E\text{-}13x^4 + 4E\text{-}09x^3 – 2E\text{-}05x^2 + 0.0472x + 34.356$ where y is the biparietal diameter and x is the weight in grams with a correlation of determination of $r^2 = 0.9994$ ($P < 0.0001$) in Nigerian fetuses in Jos. Other relationships can be calculated outside the skull. Fig. 6.81 shows relationship of weight with abdominal circumference. From the graph, it can be seen that there is a positive polynomial correlation between abdominal circumference and weight with a correlation of determination of $r^2 = 0.9993$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the forth order polynomial regression equation $y = – 3E\text{-}12x^4 + 2E\text{-}08x^3 – 9E\text{-}05x^2 + 0.1947x + 95.592$ where y is biparietal diameter and x is the fetal weight in grams with a correlation of determination of $r^2 = 0.9992$ ($P < 0.0001$). Fig. 6.82 shows relationship between weight and femur length. There is a positive polynomial correlation between weight and femur length with a correlation of determination of $r^2 = 0.9972$ ($P < 0.0001$) in Nigerian fetuses in Jos. The relationship is best described by the forth order polynomial regression equation $y = 1E\text{-}12x^4 – 8E\text{-}09x^3 + 2E\text{-}05x^2 – 0.009x + 43.172$ where y is femur length and x is the fetal weight in grams.

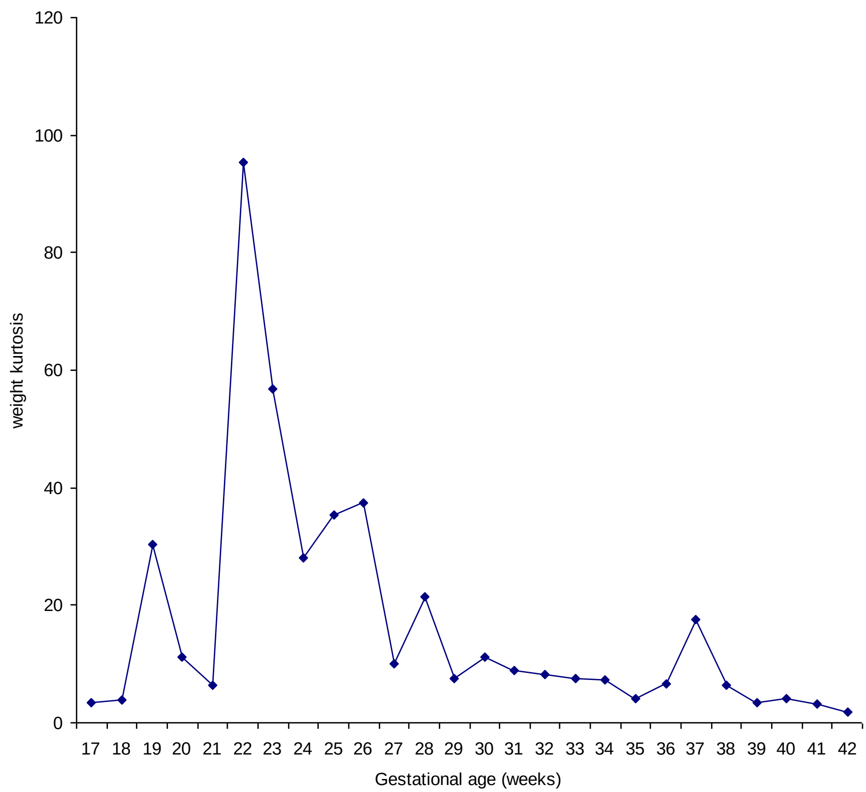

Fig. 6.74 *Weight data of 12,080 fetuses subjected to kurtosis analysis at different gestational age ranging from 12 – 42 weeks.*

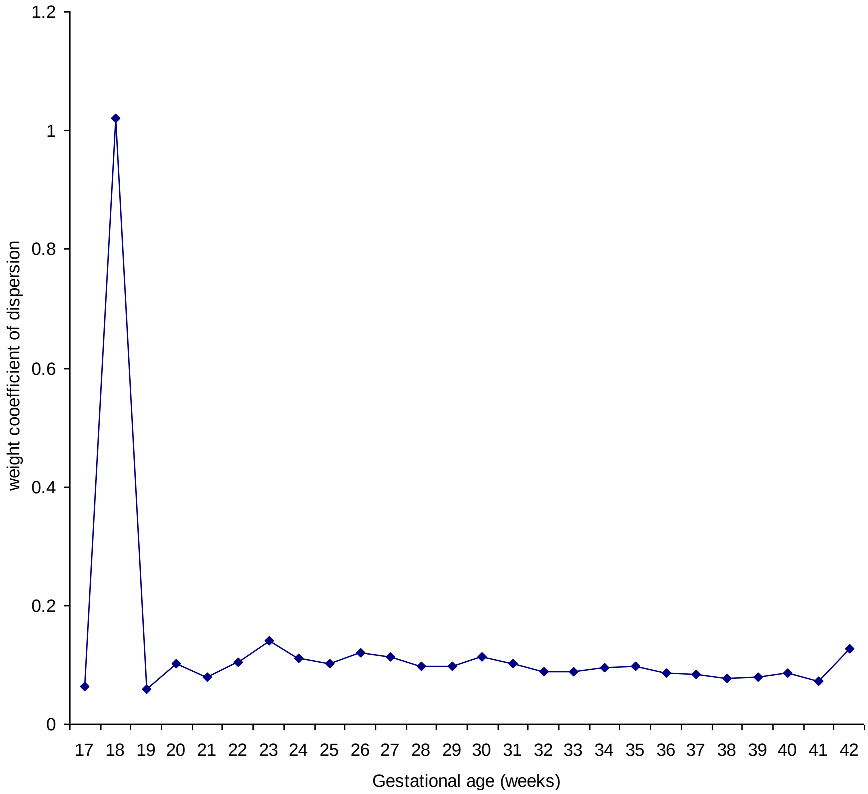

Fig. 6.75 *Weight coefficient of dispersion in 12,080 fetuses of gestational ages between 12 to 42 weeks.*

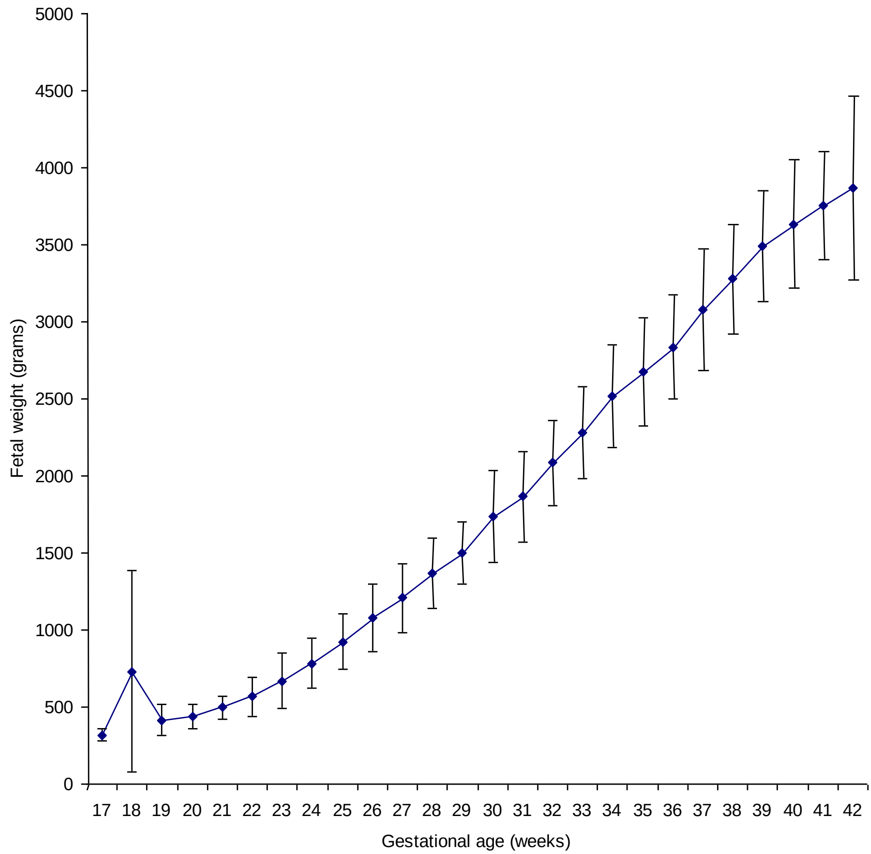

Fig. 6.76 *Mean fetal weight values in 12,080 fetuses of women at different gestational ages between 12 – 42 weeks. The vertical bars show the values of ±SD.*

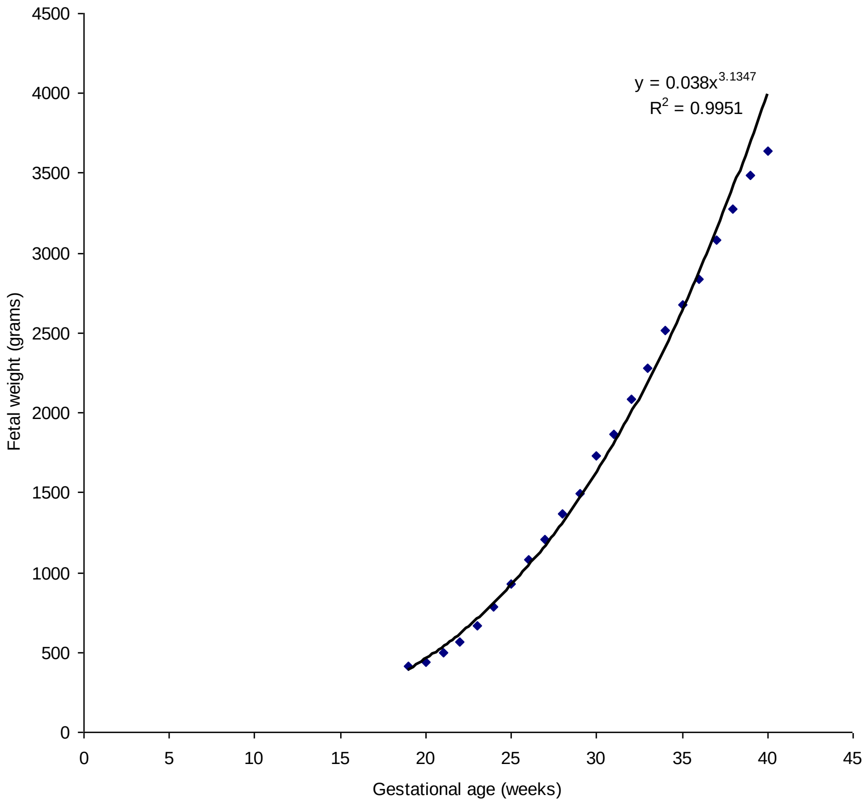

Fig. 6.77 *Correlation and regression equation of mean fetal weight values in 12,080 Nigerian fetuses in Jos plotted against gestational age.*

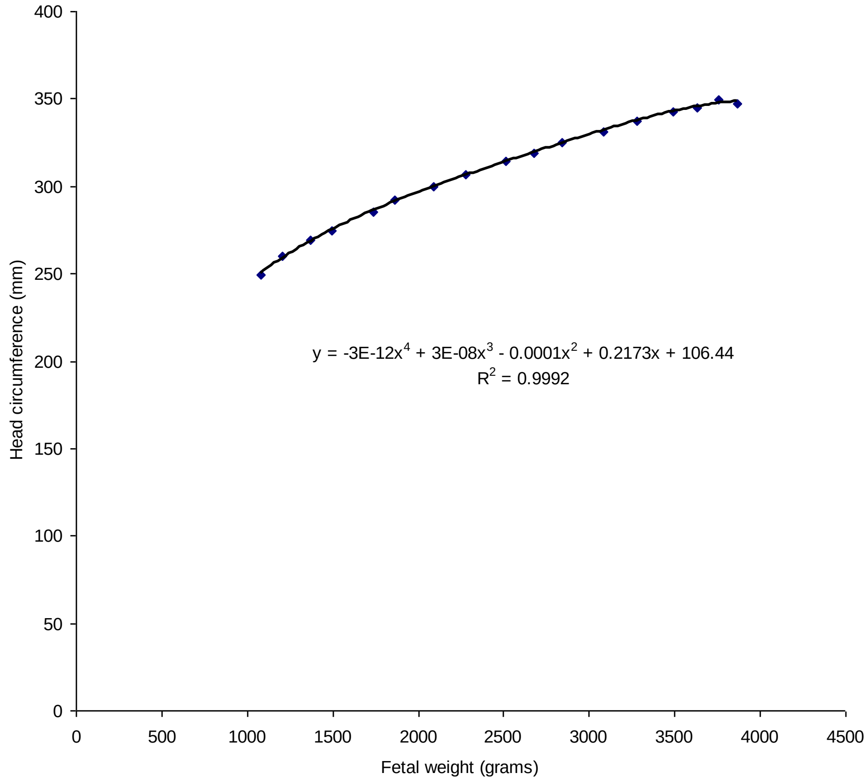

Fig. 6.78 *Correlation and regression equation of mean head circumference values in 12,080 Nigerian fetuses in Jos plotted against fetal weight in grams.*

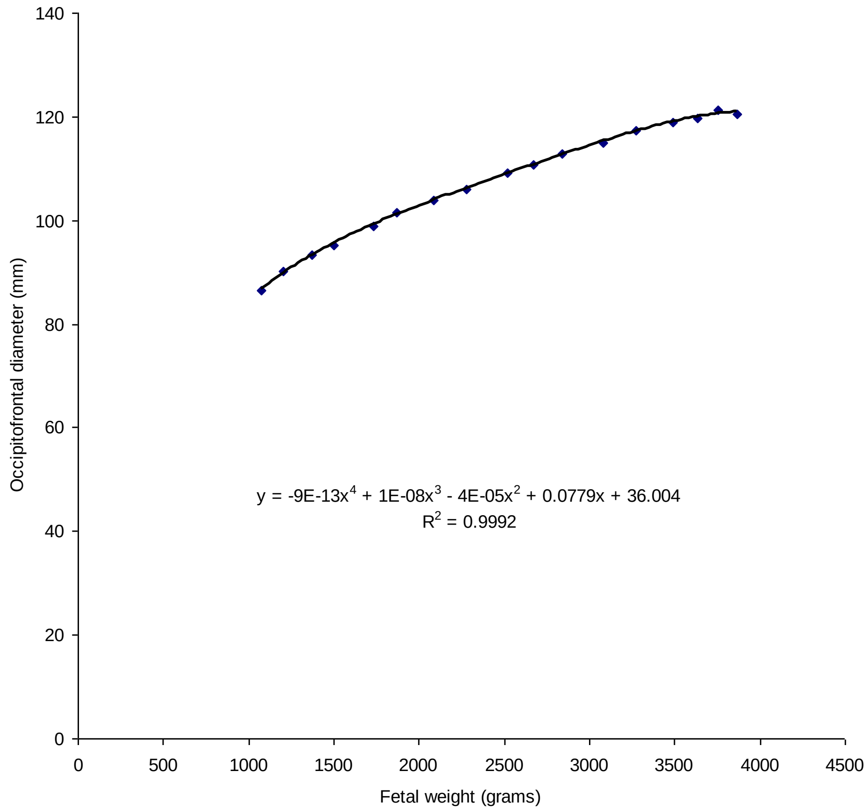

Fig. 6.79 *Correlation and regression equation of mean occipitofrontal diameter values in 12,080 Nigerian fetuses in Jos plotted against fetal weight in grams.*

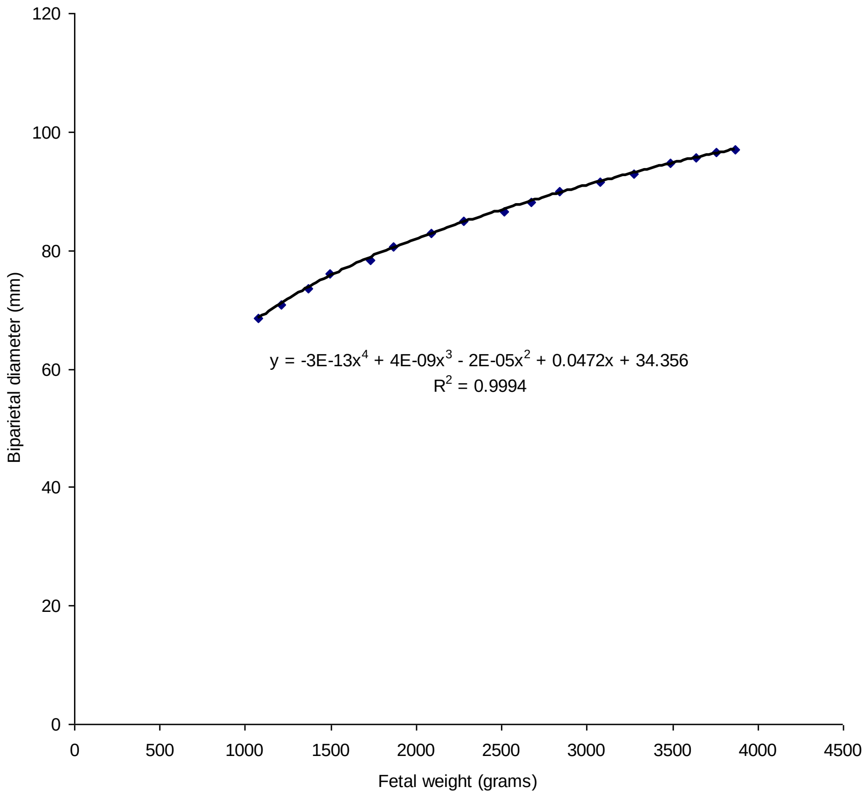

Fig. 6.80 *Correlation and regression equation of mean biparietal diameter values in 12,080 Nigerian fetuses in Jos plotted against fetal weight in grams.*

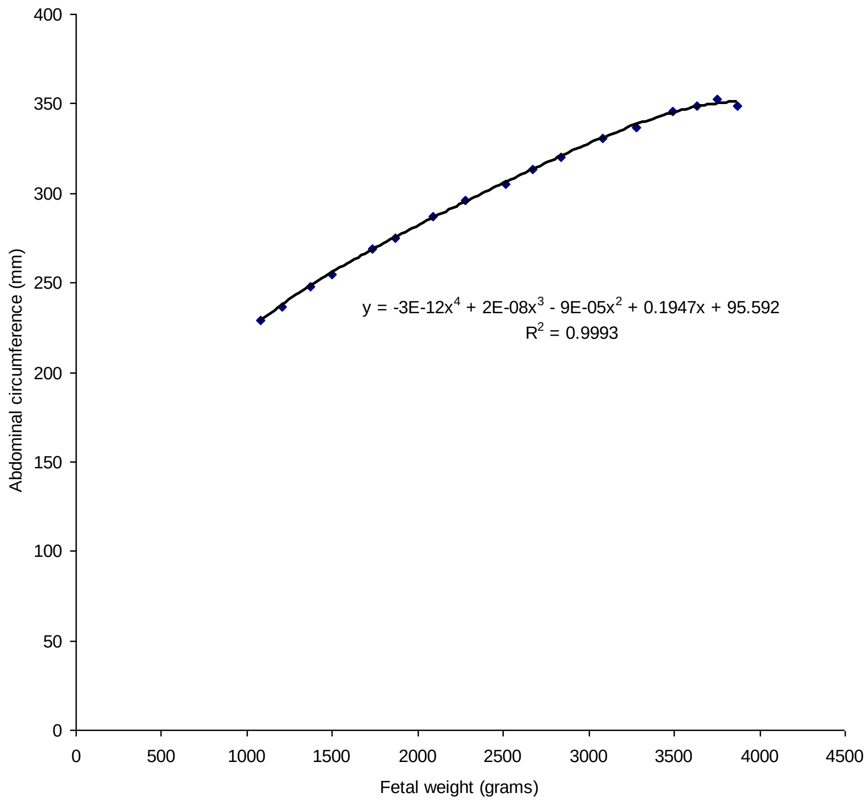

Fig. 6.81 *Correlation and regression equation of mean abdominal circumference values in 12,080 Nigerian fetuses in Jos plotted against fetal weight in grams.*

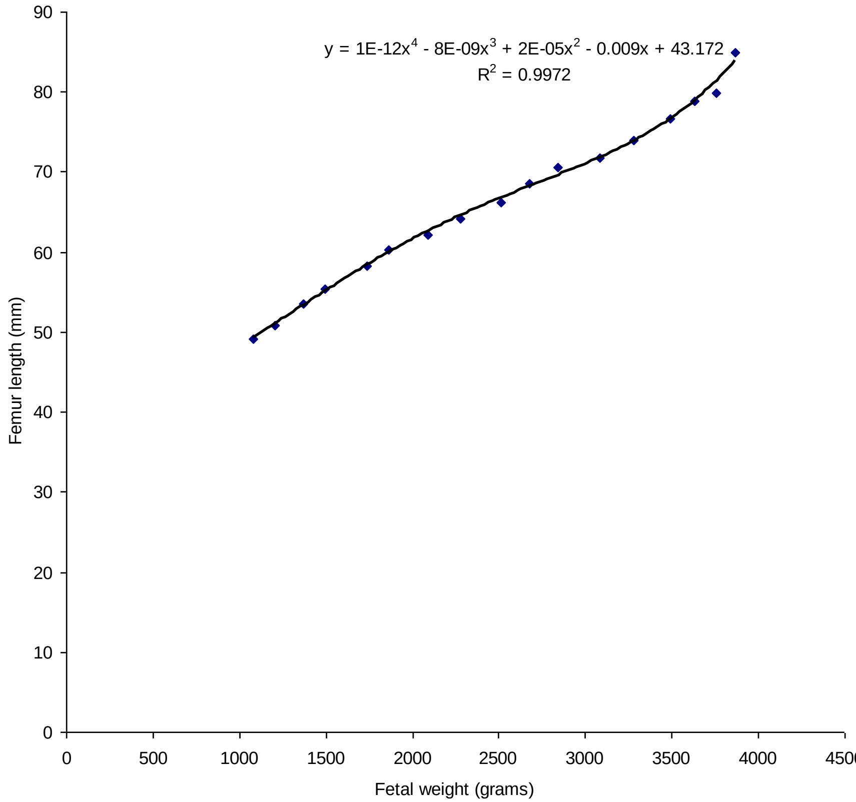

Fig. 6.82 *Correlation and regression equation of mean femur length values in 12,080 Nigerian fetuses in Jos plotted against fetal weight in grams.*

Fig. 6.83 is a graph showing fetal weight gain from 17 – 42 weeks. From this graph, it can be seen that the human fetus gains the highest weight at 18 weeks but loses it by 19 weeks before it starts gaining weight again as from 20 weeks; and the weight gain keeps rising and becomes relatively constant towards the end of the third trimester. Fig. 6.84 shows histogram of fetal weight during the 5th month of intrauterine life while Fig. 6.85 shows histogram of fetal weight gain during 5th month of life. From this histogram it can be seen that the human fetus loses weight considerably at 19 weeks. Taking a look at the growth velocity of fetal biparietal diameter, occipitofrontal diameter, head circumference, abdominal circumference and fetal femur length from 13 – 42 weeks, it can be seen that there is a drop in the growth velocity of these parameters at 19 weeks. At the same time the fetus losses about 318g during this period which seems not to happen by chance. Most likely, something takes place during this period which is yet to be unraveled – *the "19th week gestation problem".*

When blood sample of pregnant women and non-pregnant women were analyzed, it was found out that there was significantly higher uric acid level in pregnant women as compared with the non-pregnant group. Among those that were pregnant, it also found out that women with multiple pregnancies as confirmed by ultrasound scan had significantly higher uric acid level than those with singleton pregnancy that fetuses are responsible for the production of the high uric acid seen in pregnancy. One other interesting finding that was discovered in the course of this study was that women diagnosed with molar pregnancy had significantly higher uric acid level than those with multiple gestations confirming that fetal tissue is likely to be the main source of uric acid as reported by Simmonds *et al* (1984) and Cohen *et al* (2002). Fig. 6.86 shows the variation of uric acid during normal singleton pregnancy from the 3rd month of life up to the 10th month.

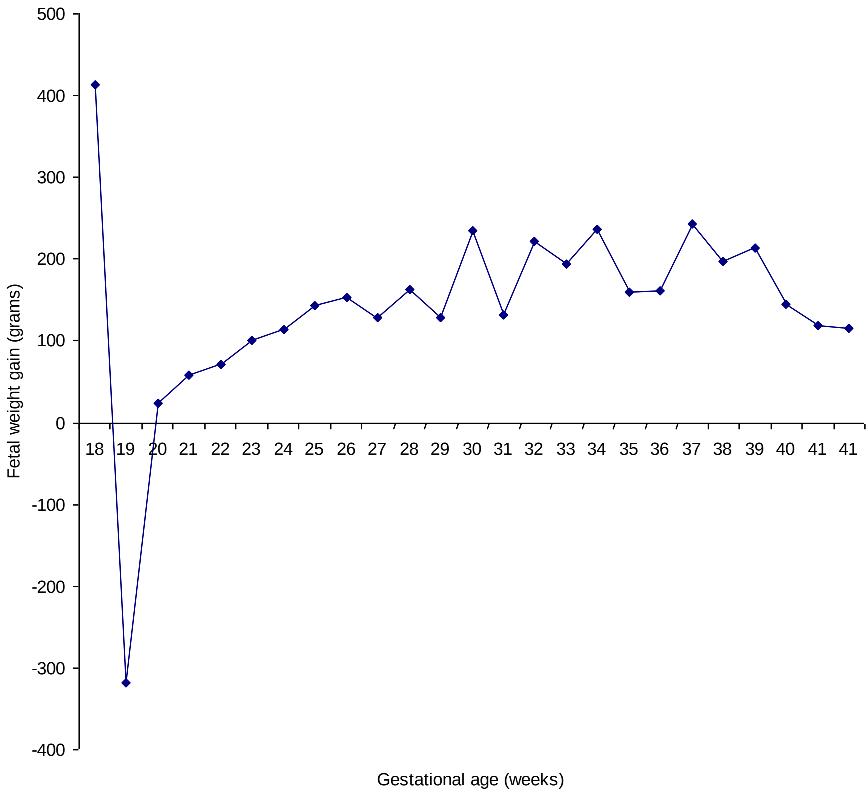

Fig. 6.83 *Mean fetal weight gain during normal pregnancy.*

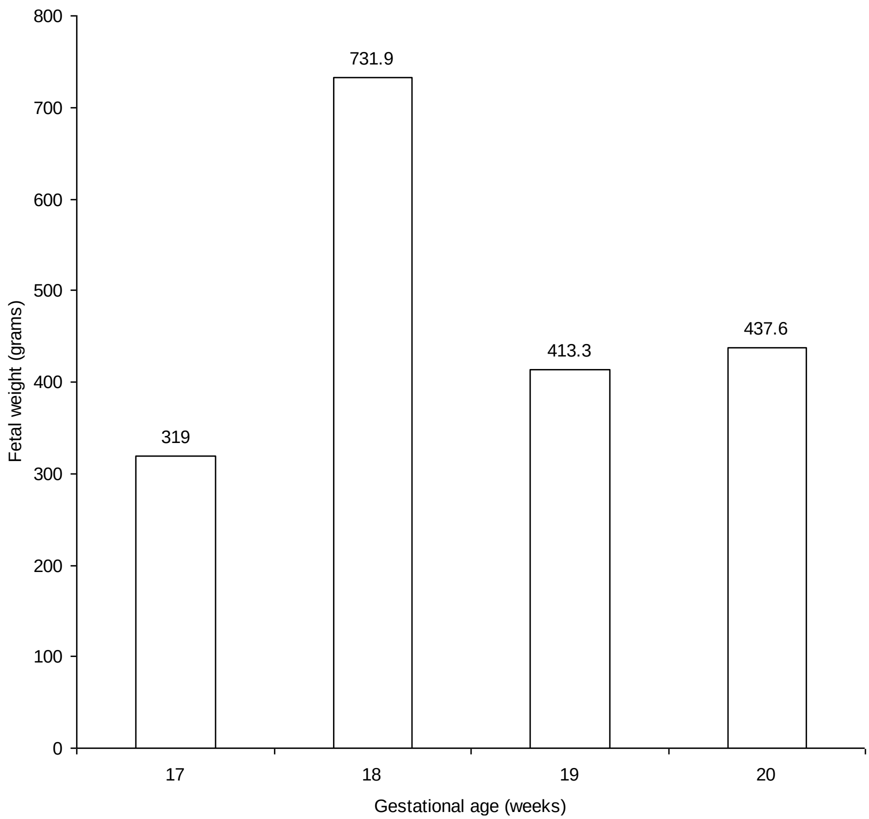

Fig. 6.84 *Mean fetal weight at 5 months.*

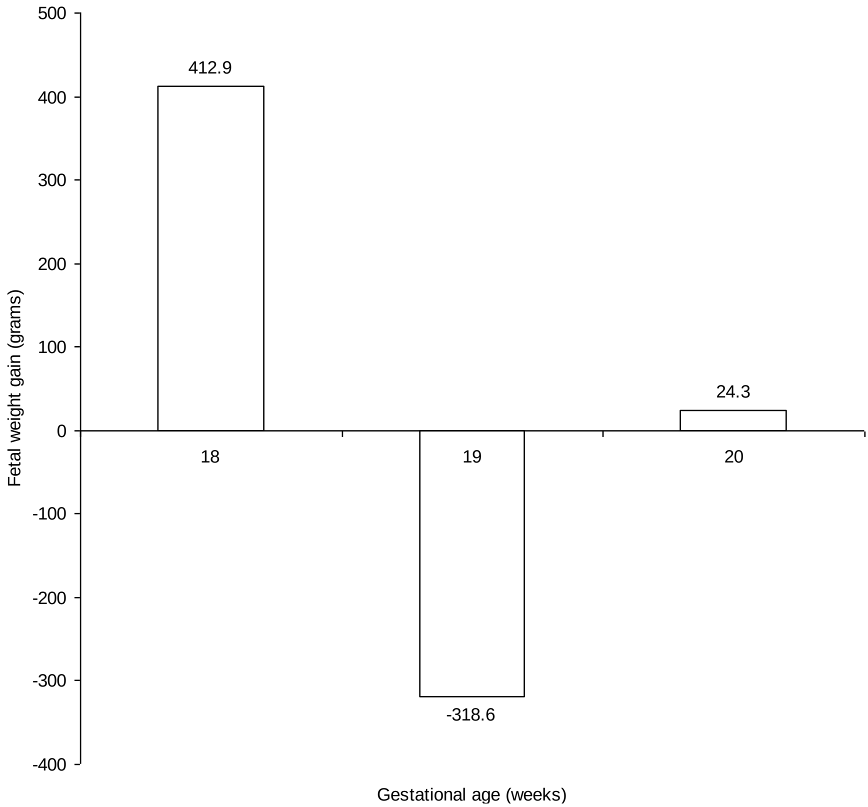

Fig. 6.85 *Mean fetal weight gain at 5 months.*

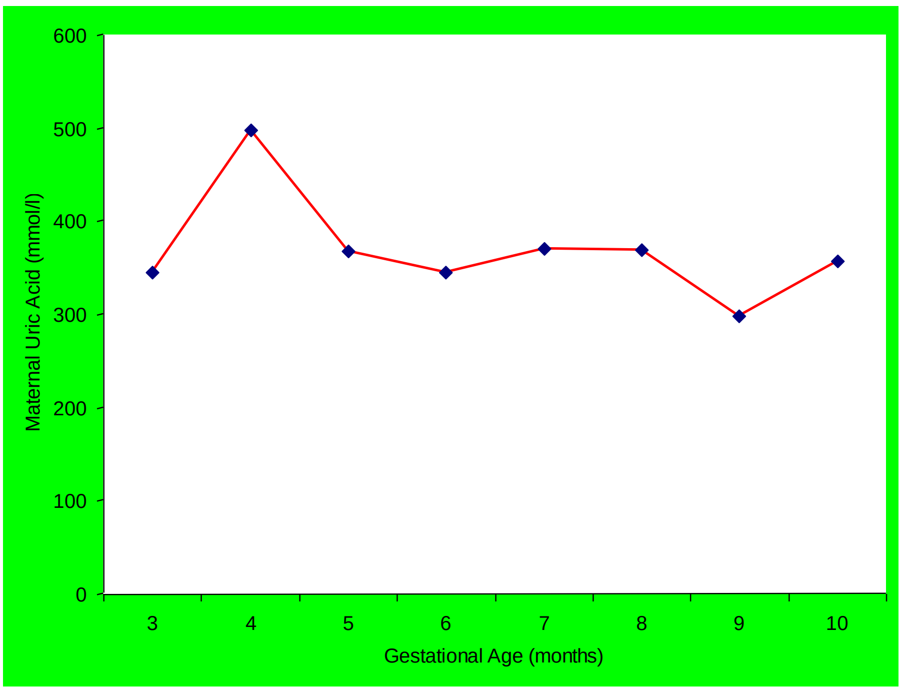

Fig. 6.86 *Uric Acid level in Maternal Circulation during Normal Singleton Pregnancy.*