GROWTH CURVES DERIVED FROM ULTRASONOGRAPHIC FETAL PARAMETERS IN A TURKISH POPULATION

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SUMMARY
In this longitudinal study, ultrasonographically measured fetal biparietal diameter (BPD), femur length (FL), head circumference (HC), abdominal circumference (AC), humerus length (HL), biocular diameter (BOD) and for the control of BPD measurements cephalic index (CI) were evaluated in relation to menstrual age in 30 normal fetuses. The results indicated a high degree of positive correlation between the measurements and gestational age. When compared to other data, BPD, FL, HL and BOD growth curves were in good agreement with the growth curves presented in other studies, and were in normal confidence limits. The HC and AC growth curves were in agreement in the lst and 2nd trimesters, yielding very similar results, but in the 3rd trimester the differences increased gradually nearing term, the values remaining in the lower confidence limits. The differences in the growth curves may result from different population studies, genetic variations or from technical errors. It is concluded that, in the evaluation of fetal growth in-utero, utilization of multiple parameters give more reliable results. Considering the different results in the tables presented by various authors, we believe that it would be appropriate to establish new nomograms which will represent Turkish population better, hoping that this preliminary study will initiate interest in this field.

Key Words: Ultrasonographic fetal parameters, growth curves, fetal growth profile.

INTRODUCTION

Assessment of fetal growth by ultrasonographically measured fetal parameters is an established and reliable method (1, 2). It can be used for many purposes: Gestational age determinations in normal and complicated pregnancies, evaluation of fetal status and growth profile, and diagnosing fetal congenital anomalies. The parameters that are used most, consist of biparietal diameter (BPD), femur length (FL), head circumference (HC), abdominal circumference (AC), and the less used ones are humerus length (HL) and biocular diameter (BOD) (1 - 21). The pooled data in the literature indicates that all parameters have a high degree of positive correlation in relation to menstrual age, although there are differences between the mean values reported in different studies (1 - 21). However, these differences are not significant in common practice.

In the present study, all parameters mentioned above were measured in 30 normal fetuses and the results were compared with other data. The goal was to achieve competence in ultrasound procedures, to form a team for future studies and to establish normal parameter tables for the population we attend.

MATERIALS AND METHODS

This study was conducted in the Service of Gynecology and Obstetrics II, Okmeydanı Social Security Hospital, between October 1985 - September 1986. 30 pregnant patients were chosen for analysis by the following criteria: 1) a history of regular menses, 2) known date of the beginning of the last menstrual period, 3) close agreement ($\pm$ 1 week) between the menstrual age and the clinical evaluation, 4) delivery occured within $\pm$ 2 weeks of expected date of confinement, 5) absence of maternal disease known to affect normal fetal growth (e.g., diabetes mellitus, chronic hypertension), and 6) absence of multiple gestation in the current pregnancy. The Dubowitz Score was confirmatory on the neonatal maturity in each case (22).

All examinations were performed using a linear - array real - time sonographic system (Siemens Sonoline SL scanner) with a 3.5 MHz frequency transducer, and a caliper velocity of 1540 m/sec. The measurements were made using manually controlled electronic calipers on a freeze frame, according to the methods described previously by others (1, 2, 3, 10, 13, 16, 19).

BPD measurements were obtained through a plane containing cavum septum pellucidum anteriorly and falx cerebri posteriorly, from the outer to inner aspects of the fetal skull. HC was obtained by measuring the BPD and the fronto-occipital diameter on the same plane and the circumference was calculated by using the formula for an ellipse:
$C = (D_1 + D_2) x\ 1.57$.

For AC measurements the umbilical-portal venous system was visualized and two perpendicular diameters were obtained and the circumference was calculated from the formula for an ellipse. FL was measured by defining both ends of the calcified portion of the shaft, excluding the femur head. For HL measurements the transducer was rotated alongside the fetal chest until a clear image was obtained. The fetal orbits were identified in three different fetal head positions: occipitoposterior, occipitotransverse, and occipitoanterior and the outer orbital diameters were measured from the lateral border of one orbit to the opposite lateral border of the other. The cephalic index (CI) was calculated from the formula: CI — Biparietal diameter / occipitofrontal diameter X 100 % (23).

The fetuses were examined three to eight times during gestation. On each occasion, several measurements were made for each parameter until three closely corresponding results were obtained within a 2 mm range (9, 23), and the average was taken. Each examination interval was centered on the week (e.g., 16 week interval — 15.51 — 16.49 weeks). The data obtained were plotted on charts and statistically analysed (McIntosh,Statview[512] + system) to obtain regression curves from mean values at each weekly interval. The data acquired from the parameter measurements were presented as the mean values in the tables.

RESULTS

The relation of the BPD, CI, FL, HC, AC, HL, and BOD to menstrual age are illustrated through Figures 1 to 7 respectively as the predicted mean ultrasound measurements. The polynomial function best describing the relation between the parameters and menstrual age are given in Table I. All parameters displayed good correlation with gestational age. The predicted values of parameters for specific points in gestation are compared with the data from other studies through Tables II to VI.

BPD growth was fairly linear up to 28 weeks of gestation and the growth rate was 3.2 ± 0.2 mm/week; then decreasing gradually between 28 - 41 weeks from a rate of 2.5 to 1.5 mm/week. The predicted mean BPD values at various points in gestation agreed relatively well with the values reported by others. The best correlation with our results was the data of Hadlock et al (3), yielding almost identical results. The greatest difference between our values and the data of Shepard et al (3) was 2 mm, and with the data of Jeanty et al (3) and Deter et al (3) it was 3 mm (Table II).

Predicted mean CI values as a function of menstrual age was shown in Figure 2. This ratio was almost constant during gestation and it was calculated as 79 % on the average.

FL growth was fairly linear up to 28 weeks and the growth rate was 2.7 mm per week; then it decreased gradually to 1.5 mm/week in the last weeks of gestation. The predicted mean values at specific points of gestation were in well agreement with the data of Jeanty et al (13), and the mean difference was 1 mm (range, 1 - 2 mm). With the results of Hadlock et al (1) our values differed 3 mm between 24 - 30 weeks and 4 mm at 32 weeks' gestation. The differences between our values and that of Yeh et al (10) were greatest between 16 - 20 weeks (5 - 6 mm), then declining slowly to 2 mm near term (Table III).

Computed mean HC values correlated well with the results of Jeanty et al (19), and Hadlock et al (17) and the greatest difference was 17 - 18 mm in the last trimester. With respect to the data of Deter et al (1) our values differed greately between 32 - 40 weeks (24 - 33 mm), and with respect to the work of Sabbagha et al (7), the major differences were 18 mm between 28 - 30 weeks and 13 mm at 36 weeks (Table IV).

AC mean values were shown in Table V. The data of Jeanty et al (16) has consistently lower values than the present study, the differences being 11 - 14 mm between 14 - 20 weeks and 9 - 15 mm at term. The differences between the predicted mean values of this study and the work of Deter et al (14) and Sabbagha et al (7) were 11 - 39 mm during 26 - 40 weeks, increasing near term. The weekly growth rate was 22 mm in the 1st and 2nd trimesters and declining to 16 mm/week near term.

Computed mean HL values agreed well with the results of Jeanty et al (18) after 18 weeks' gestation, and it was in the range of 1 - 2 mm. BOD measurements gave almost identical results with the work of Jeanty et al (20). The growth rate was 1.5 - 2 mm/week for HL and 1 - 2 mm/week for BOD (Table VI).

DISCUSSION

Fetal growth profile using ultrasonographic fetal parameters is an established modality. In early pregnancy, gestational sac and crown - rump length measurements make the diagnosis and dating possible. From 15 th week onwards other fetal parameters can be measured and used reliably (2, 3). The most widely used parameter is BPD and it shows a good correlation with gestational age (1, 3, 7, 10, 16, 24) (Figure 1). The accurate BPD measurements are obtained between 15 - 28 weeks of pregnancy (3, 4) and the rate of growth is uniform and reaches its maximum at this time (25). In the present study, the weekly growth rate is found to be 3.2 ± 0.2 mm in the 14 - 28 weeks period. The accepted standard measurements of BPD are obtained from outer to inner edges of the fetal skull, at the level of thalamus and cavum septum pellucidum (22).

After 28 weeks of pregnancy, when evaluating the BPD charts, one should also consider the cephalic index (CI) (2, 7, 16, 22, 24, 26, 27). Normally, the fetal head at the level of thalamus is ovoid in shape. The two most frequent fetal head deformities, especially in advanced gestation, are brachycephaly and dolichocephaly (27). In brachycephaly the head is shortened in the anteroposterior plane and enlarged in the transverse plane (BPD), and in dolichocephaly the reverse occurs (2, 10, 27). Normal CI values are reported to be between 78 - 80 % (26, 27) and values less than 75 % are accepted as dolichocephaly and values above 85 % as brachycephaly (2, 3, 22, 26, 27). In these circumstances other parameters should be used (22, 27). In the present study, CI values demonstrate no significant change with increasing gestational age and are found to be 79 % on the average (Figure 2). Hadlock et al (26) reported CI as 78.3 ± 4.4 %. These findings suggest that normal values can be accepted as 79 %.

Although it is not clear whether the degree of variation in BPD results from racial or socioeconomic differences, maternal disease or fetal head shape, it is agreed that, the variation in BPD measured by ultrasound for a given age of gestation becomes greater as pregnancy progresses (5). Thus, earlier measurements are more useful than later ones. The errors which affect BPD measurements are mostly observer errors, genetic variations, use of different nomograms, prematurity, effect of head shape and positional problems (8, 22).

Another reliable parameter is FL (8 - 13). Since it is a long bone and there is easy access for visualization, it is used when a reliable BPD measurement cannot be obtained (1, 8 - 11, 13). The ends of the femur should be sharply depicted and should not taper (3, 9, 10). The most commonly used method is measuring the shaft of the bone, excluding the femoral head (22). The shaft of the femur is the easiest fetal long bone to visualize and measure. From 36 weeks' gestation onward, there is slight difficulty in obtaining well-defined ends at both ends of the diaphysis (11). The femur can be identified from 8 weeks' gestation and measured accurately from 10 weeks on (9). FL measurement is also important in detecting fetal limb anomalies and in intrauterine growth retardation (1, 9, 12, 13). It is an accurate means of establishing gestational age (7, 8, 10, 13, 22, 26, 28). Best results are obtained with a linear-array transducer, because measurements obtained by sector scanners give a longer bone image (7). FL variability is greater than BPD and also widens as pregnancy progresses (7).

HC is an important parameter for the evaluation of gestational age and intrauterine growth retardation. The ideal plane is the same as that of the one used to measure BPD (1). It can be calculated from the equation for the circumference of an ellipse: $C - (D_1 + D_2) \times 1.57$, or by a map reader technique (19, 24). Although the differences between the two techniques are negligible in clinical practice (19), it is reported that directly measured circumferences with a map reader may be significantly larger than those indirectly calculated from diameters (7). For this reason, the technique in obtaining HC data should be indicated on the reports (7) (Table IV).

Hadlock et al reported that, fetal head deformities may adversely affect BPD measurements (26) and HC can be substituted, because it is considered to be less affected (17, 24, 27). In late pregnancy , when the head is larger than the transducer, some guessing is necessary for measuring HC. This decreases the accuracy of the predictions based on this parameter (19). The growth of HC gives a good correlation with gestational age; the growth rate has been found to be changing from 16 mm/week to 4 mm/week when pregnancy advances (1). In the present study, it is 13 mm/week in early gestation and 4.5 mm/week at term.

AC measurements are used mostly as an adjunct to BPD and FL measurements to evaluate fetal growth, because the fetal abdomen contains the largest intraabdominal organ: liver, and this organ is the first one which is affected by growth retardation (1). As with the HC, the actual measurement may employ a map measurer or the average diameter method calculated by the formula used for an ellipse (16, 24). The section used to measure AC is through the liver at a level that includes the horizontal portion of the portal sinus (1, 15, 22, 24). The AC has a relationship to gestational age similar to that of the BPD, i.e., a fairly linear one until the last weeks of pregnancy, when there is some tapering of the growth and a widening of the standard deviation (22, 24). This flattening does not, however, appear to be as marked as of the BPD (16, 24), which is also noted in the present study (Figure 5).

AC has a much higher rate of intraobserver and interobserver variability than the BPD and the FL measurements (16). Thus, a single diameter does not properly describe the size of the abdomen. Variations of the configuration of the abomen with breathing movements or during compression by the transducer further increases its variability (1, 16). There are differences in the variability of AC at various stages of pregnancy as reported before (1) (Table V.) The growth rate is reported to be constant between 10 and 12 mm (1), in the present study it is 8 to 9.5 mm.

Humerus is a long bone and can be used either for the diagnosis of congenital syndromes that affect the limbs or as an adjunct to establish gestational age (18). The humerus is very close to the anterior abdominal wall and sometimes it is difficult to delineate correctly (9, 18), a problem which is encountered during the present study. Our results are in accordance with the results of Jeanty et al, and the correlation with gestational age is good (Figure 4, Table VI).

Fetal ocular biometry can be used to estimate gestational age and to examine fetuses at risk for hypo or hypertelorism, anophtalmos, and micropthalmos (1, 20, 21). It is impossible to obtain a reliable BPD measurement when the fetal head is facing straight up or down (21). However, the orbits can be identified and measured. Care should be given while taking measurements because an incorrect plane will ultimately result in erroneous results (20, 21). One can verify the results by checking that the sum of the interocular distance plus two times the ocular diameter is equal to the biocular diameter (20). The fetal orbits can be identified in three different fetal head positions: occipitotransverse, occipitoposterior, and occipitoanterior (21). The correlation with gestational age is very good (20, 21), which is consistent with our findings (Figure 7).

Although fetal parameters are considered to be reliable tools in obstetric practice, some problems mentioned above are still present. Thus, one should know advantages and disadvantages of fetal parameter measurements when intending to use it in the evaluation of fetal growth.

All parameters seem to correlate well with gestational age in individual studies, as in the present one (Figures 1 and 3 to 7, and Table I). On the other hand, there are noted differences in the mean values for a given parameter with different investigators (Tables II to VI). The differences are more pronounced in AC and HC mean values (Tables III - IV), because they are too sensitive to growth variabilities. It can be noted that, in the early weeks of pregnancy many authors reported very close results of AC and HC measurements, but near term the mean values differed considerably in some studies. Our results are different from the others in the 0.5 to 1 standard deviation range in BPD, FL, HL and BOD values, but for HC and AC the differences are noticeable especially near term (Tables III - IV). The differences may result from different population studies, genetic variations or from technical problems (29, 30). The existence of such differences illustrates the need for establishing normal values for every parameter in population studies (1).

In summary, there is no single parameter that clearly defines fetal growth, and one should not rely on one parameter when evaluating the fetus in-utero. The range and variability become greater approaching term for most parameter measurements, so, the best time to obtain any measurement is between 16 - 22 weeks of pregnancy and then serial measurements of multiple parameters are needed in the evaluation of fetal growth (31).

Our nomograms correlate well with the work of Jeanty et al for FL, HC, AC, HL, and BOD, and for BPD with the ones presented by Hadlock et al and Shepard et al. We believe that, our tables can be a preliminary data base for our country and we urge that all studies on this field should be collaborative to establish standard values for the Turkish Population.

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Table I: Best fitting regression models for various parameters.

x / y	Polynominal equation	r^2	Illustrated in figure
GA / BPD	$y = -33.678 + 4.853x - 0.041x^2$	.993	1
GA / CI	$y = 0.032x + 78.243$		2
GA / FL	$y = -24.882 + 3.147x - 0.016x^2$	.996	3
GA / HC	$y = -123.874 + 18.597x - 0.184x^2$	.993	4
GA / AC	$y = -61.278 + 11.452x - 0.041x^2$	.996	5
GA / HL	$y = -12.903 + 2.583x - 0.016x^2$	.988	6
GA / BOD	$y = -11.157 + 2.547x - 0.019x^2$	.988	7

GA = Gestational age.

Table II: Comparison of predicted BPD values at specific points in gestation

	Reference /BPD (mm)					
Gestational age (weeks)	This study *	Jeanty * (3)	Deter * (3)	Hadlock + (3)	Shepard + (3)	Sabbagha (7)
14	26	28	24	27	28	
16	33	35	31	33	34	37
18	40	42	38	40	40	43
20	47	48	45	46	46	47
22	53	55	51	53	52	53
24	59	61	57	58	57	59
26	65	67	63	64	63	66
28	70	72	69	70	68	72
30	75	77	74	75	73	78
32	79	82	78	79	78	83
34	84	86	82	84	83	87
36	88	89	86	88	88	90
38	92	91	89	91	92	93
40	95	93	92	95	97	95

* — Longitudinal study
\+ — Cross - sectional study

Table III: Comparison of predicted Femur Lengths at points in gestation

	Reference / Femur Length (mm)			
Gestational age (weeks)	This study	Jeanty (13)	Hadlock (1)	Yeh (10)
14	16	14	15	
16	21	20	21	27
18	26	25	27	31
20	31	31	33	36
22	37	36	39	40
24	41	42	44	44
26	46	47	49	48
28	51	52	54	53
30	55	56	58	57
32	59	61	63	61
34	64	65	66	66
36	68	68	70	70
38	72	71	73	74
40	75	74	76	78

Table IV: Comparison of mean Head Circumference (HC) values at specific weeks in gestation

Menstrual age (weeks)	Reference / HC (mm)				
	This * study	Jeanty * (19)	Hadlock + (17)	Deter + (1)	Sabbagha (7)
14	100	101	98	101	
16	126	126	122	128	
18	151	151	148	154	160
20	174	175	177	179	180
22	196	198	193	204	200
24	216	221	221	227	220
26	235	242	241	249	240
28	252	262	271	269	270
30	268	281	277	288	285
32	282	297	292	306	290
34	296	312	309	322	305
36	307	325	322	336	320
38	317	335	336	348	325
40	326	343	345	359	335

* = Computed values
\+ = Measured values

Table V: Comparison of mean Abdominal Circumference (AC) values at specific weeks in gestation

Menstrual age (weeks)	Reference / AC (mm)				
	This * study	Jeanty * (16)	Deter + (16)	Hadlock + (14)	Sabbagha (7)
14	91	77	84	81	
16	111	98	106	105	
18	131	119	128	127	131
20	152	141	150	154	154
22	171	163	172	169	180
24	190	184	194	197	205
26	209	205	216	220	221
28	227	225	238	246	253
30	245	244	260	252	274
32	263	262	282	271	287
34	281	279	304	298	301
36	298	293	326	312	333
38	315	306	348	339	357
40	331	316	370	349	361

* = Computed values
\+ = Measured values

Table VI: Comparison of predicted Humerus Lengths (HL) and Biocular Distances (BOD) at specific weeks in gestation

Menstrual age (weeks)	Reference / HL (mm)		Reference / BOD (mm)	
	This study	Jeanty (18)	This study	Jeanty (20)
14	20	14	21	20
16	24	20	25	25
18	28	25	28	29
20	32	30	32	33
22	36	35	36	36
24	40	40	39	40
26	43	44	42	43
28	47	48	45	46
30	50	51	48	49
32	53	55	51	52
34	56	58	53	54
36	59	61	56	56
38	62	63	58	58
40	65	66	60	60

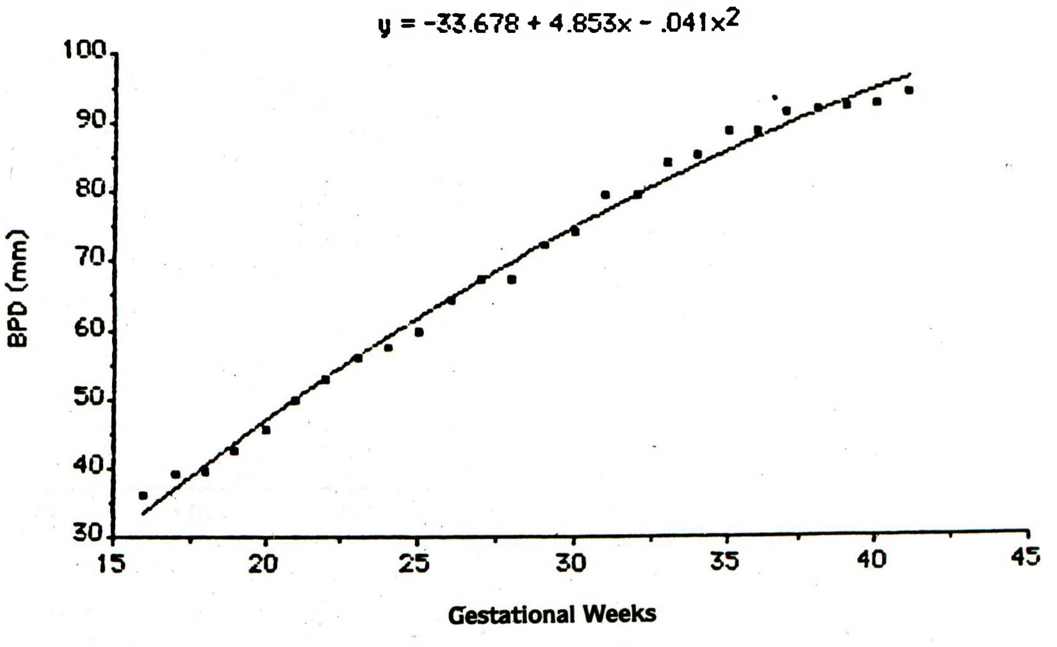

Figure-1: Curve of predicted biparietal diameter values as function of gestational age

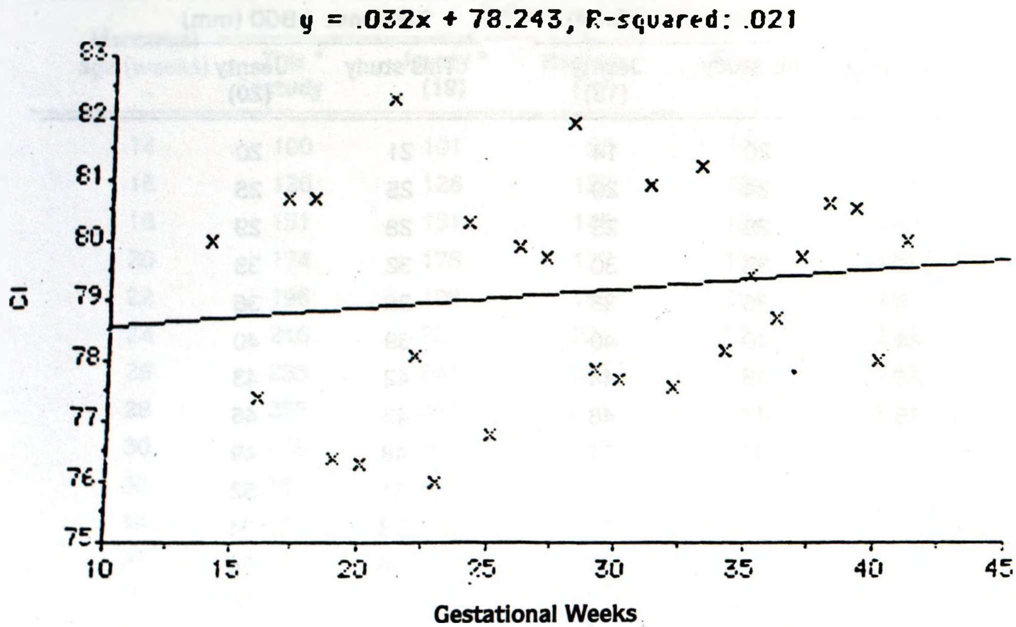

Figure-2: Distribution of mean and predicted cephalic index values at specific points in gestation

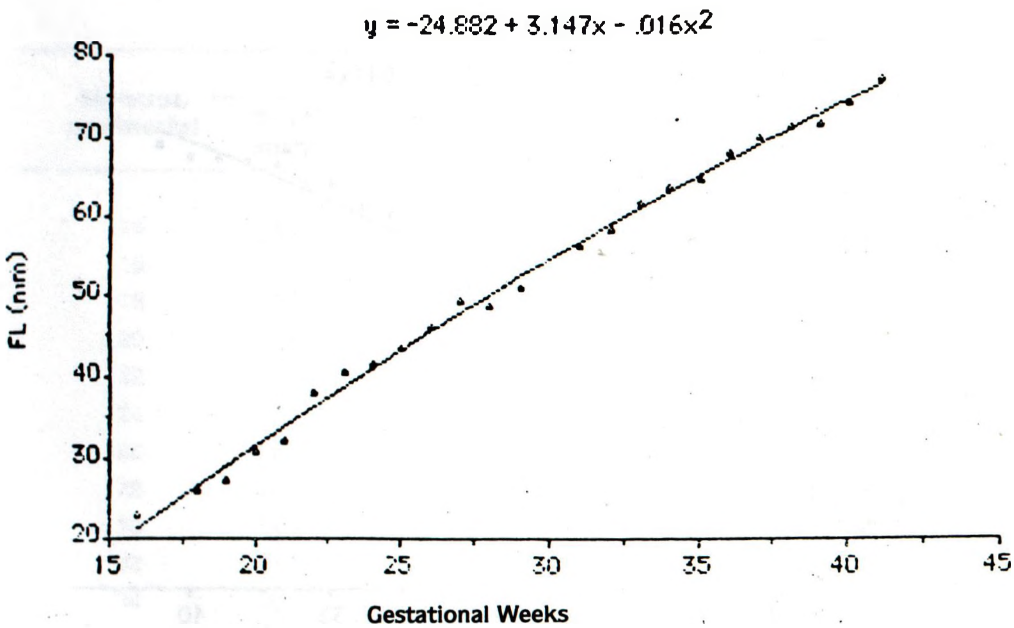

Figure-3: Curve of predicted femur length values at specific points in gestation

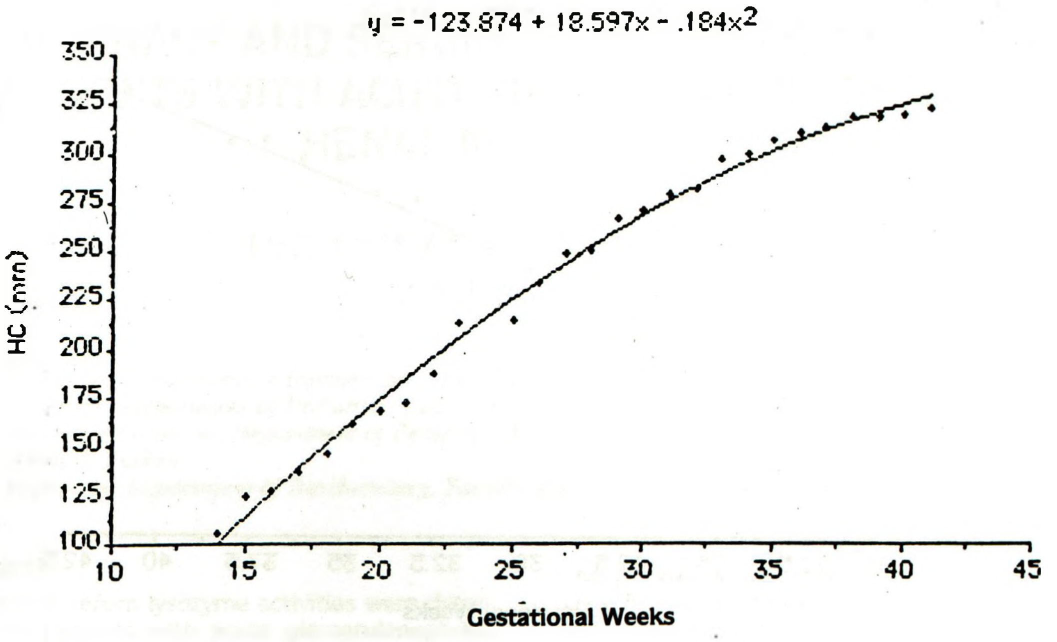

Figure-4: Curve of predicted head circumference values at specific points in gestation

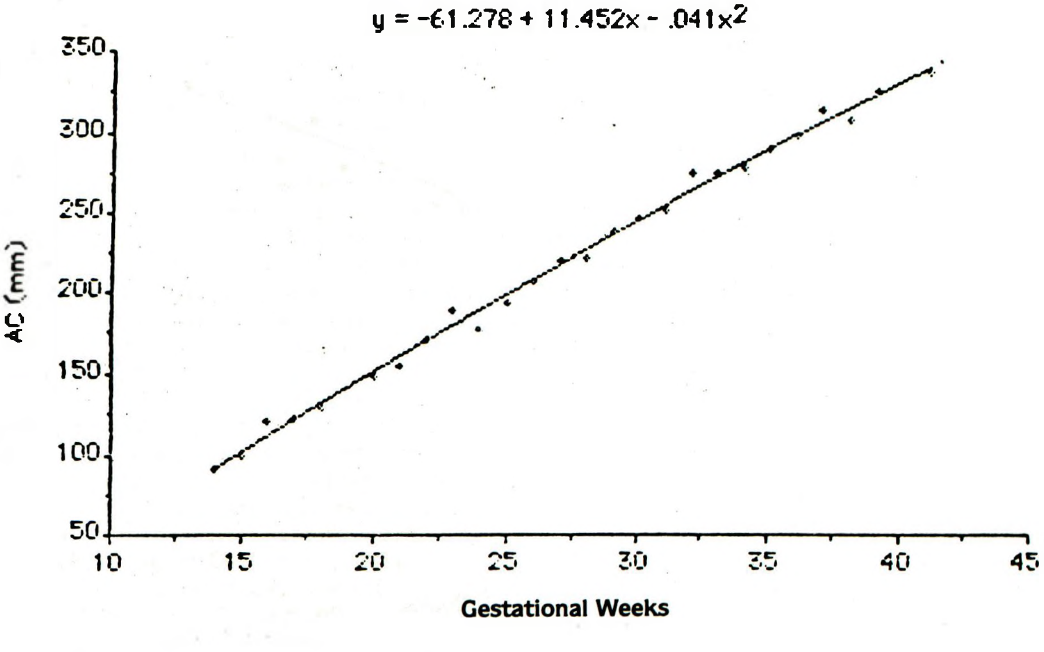

Figure-5: Curve of predicted abdominal circumference values at specific points in gestation

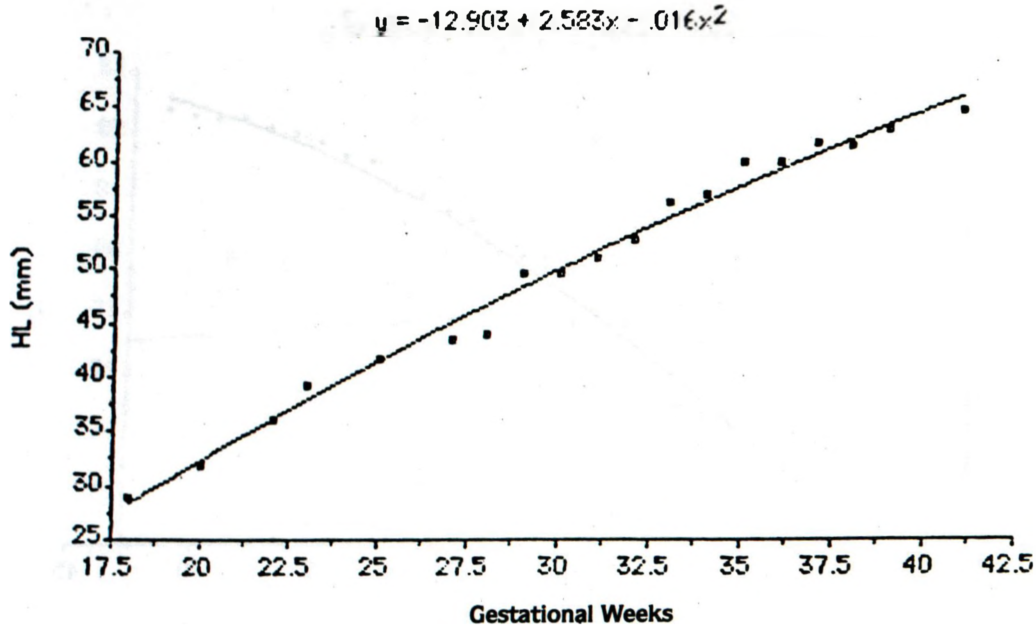

Figure-6: Curve of predicted humerus length values as function of gestational age

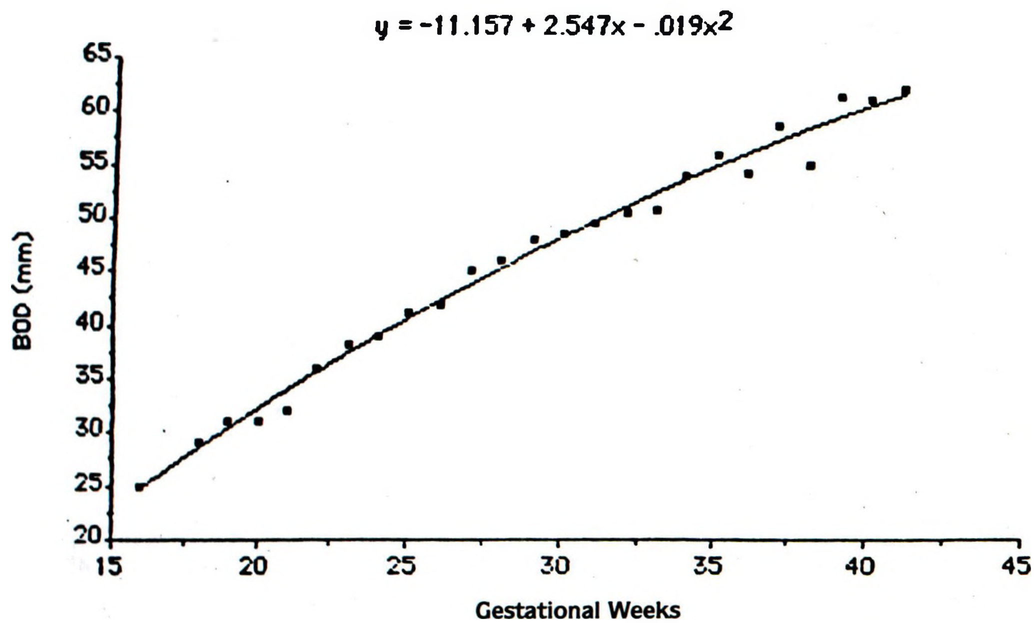

Figure-7: Curve of predicted biocular diameter values as function of gestational age