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An Assessment of Femur Growth Parameters in Human Fetuses and Their Relationship to Gestational Age

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Abstract: Fetal femur length assessment has been the subject of numerous investigations. Skeletal growth disturbances, estimation of fetal gestational age, developmental abnormality and detection of certain fetal congenital anomalies, and determination of population growth characteristics have been the objectives of different investigators' studies. The purpose of this study was to evaluate the relationships between the crown-rump length (CRL) and fetal femur growth parameters and the gestational age during the second and third trimesters. Thirty dead normal immature and premature fetuses were selected from the fetal collection at the Anatomy Department of the Medical School, Selçuk University. Depending on the fetal CRL and according to the Polin and Fox criteria, the fetal gestational age at the time of delivery was between 20 and 32 weeks. There were 15 male fetuses and 15 females. Each sex group included nine second-trimester and six third-trimester fetuses. A total of eight parametric variables were obtained from bilateral femora using a sliding caliper. Obtained data were statistically analyzed by Student's t-test and Pearson correlation coefficients. A significant relationship between the studied fetal growth parameters and the gestational age was found. From analysis of the data, it appears that fetal CRL and femur growth parameters are accurate for the calculation of gestational age.

Key Words: Fetuses, Growth parameters, Femur, Development

Introduction

In the last 20 years there has been increased awareness of the importance of assessing aborted embryos and fetuses for evidence of developmental abnormalities. Fetal femur length has been one of the standards used as a morphometric evaluation of fetal growth and development in second- and third-trimester fetuses. For the same purpose, crown– rump length (1-4), biparietal diameter, head and body circumference and cephalic index standards were used (5-7). Skeletal growth disturbances (8-12), estimation of fetal gestational age (7,13-15), developmental abnormality and detection of certain fetal congenital anomalies (1,16,17), and determination of population growth characteristics (18,19) were the objectives of different investigators' studies. Graphs have been constructed on the correlation of fetal growth with gestational age (20,21) and the relationship between body and organ weight (22). Others studied the linear relationship between sacral length and gestational age (23). In most of the published studies, as in the other long bones, assessment of the fetal femur length involved by ultrasonic measurements. Concerning this subject, in the literature few parametric studies on femoral measurements in dead immature and premature fetuses were found.

The purpose of this study was to evaluate the relationships between the fetal crown-rump length, femur growth parameters and the gestational age during the second and third trimesters.

Materials and Methods

Thirty normal spontaneously immature and premature delivered dead fetuses were selected from the fetal collection at the Anatomy Department of the Medical School, Selçuk University. The original source of this collection was the Obstetrics and Gynecology Clinics of Konya city hospitals. Depending upon the measured fetal crown–rump length and according to Hesinger's criteria (2), fetal gestational age (GA) at the time of delivery was between 20 and 32 weeks. There were 15 male fetuses and 15 females. It was recognized that each sex group included nine second–trimester and six third–trimester fetuses. In order to view both sides of the fetal femora, a fine dissection in the front of the thigh was performed, the soft tissues were carefully removed and the femoral heads were removed from their joining acetabular cavities (Fig. 1). Gross morphologic malformations were not observed in our samples. All specimens used in the present study were fixed with 10% formalin solution by immersion. In addition to the crown-rump length a total of eight parametric variables were obtained from the head, neck, shaft and distal end of bilateral femora using a millimetric sliding caliper (Fig. 2). Measurements were designed as follows:

Crown–rump length (CRL): length from the crown of the head to the most dependent part of the trunk (with the neck and back in a straight line).

Head transverse diameter (HTD): maximum antero-posterior diameter of the femur head.

Head vertical diameter (HVD): maximum vertical diameter of the femur head.

Neck vertical diameter (NVD): minimum diameter of the femur neck in the supero-inferior direction.

Greater trochanter – Head fovea distance (GTHVD): distance from the tip of the greater trochanter to the center of the head fovea.

Midshaft transverse diameter (MSTD): minimum transverse diameter at the middle of the femur shaft (perimeter at the middle).

Femur length (FL): distance from the tip of the greater trochanter to the lower end of the lateral condyle.

Head fovea – Medial condyle length (HVMCL):

Figure 1. Anterior view of the femur from one of the studied specimens at 30 weeks of gestation after dissection and removal of the head from the acetabular cavity.

Figure 2. Anterior view of the femur from one the studied fetuses at 32 weeks of gestation after dissection and during performance of measurements.

distance from the center of the head fovea to the lower end of the medial condyle.

Distal breadth (DB): maximum width between the femur epicondyles.

Data were summarized as means ± standard deviation. SPSS for Windows 10.0 was used for the statistical analysis. To determine the relationships between the fetal femur parameters, CRL and GA (wk), Pearson correlation coefficients were calculated and analyzed. Student's t-test was used to compare female and male fetal femur measurements.

Results

In Tables 1 and 2 comparative results showed no significant differences in the growth patterns between the sexes during the second and third trimesters; therefore the data for both sexes were combined. In the present study, the means of the linear measurements at 20 and 32 weeks of gestation are shown in Figure 3. A comparison of these results shows that there was a variable rate of increase in linear growth. Mean increments in the linear growth of the HVMCL and FL were 26.09 mm and 26.46 mm respectively during the 12 weeks of the gestational period studied. In the specimens, the approximate growth averages of the measured parameters per week are shown in Figure 4. In HVMCL and FL growth averages were 2.17mm/week and 2.21 mm/week respectively; the other measurements exhibited variable growth averages; for example, in the proximal epiphysis the GTHVD and HTD were 0.51mm/week and 0.37mm/week respectively. In the distal epiphysis, the growth average in the DB was 0.64mm/week. The statistical comparisons of the correlations of all measured parameters are shown in Table 3. The CRL showed highly significant correlations with the GA (r = 0.997), with HVMCL (r = 0.894), and with FL (r = 0.906). Highly significant correlations were also found between HVMCL and FL (r = 0.962). The GA was found to be highly correlated with both HVMCL (r = 0.886) and FL (r = 0.905). All other measurements in Table 3 are shown to have variable degrees of significant associations between their values. Figure 5 is a comparable illustration of the relationship of the HVMCL to the CRL with 95% confidence intervals. Figure 6 represents FL as a function of GA with 95% confidence intervals.

Discussion

Accurate linear measurements of the fetus allow a more complete profile of the fetus and add a new dimension to the measurement of its growth. In the present study, the high correlations between the studied femoral parameters and GA indicate that the growth increase existed in different ranges in all of the evaluated growth parameters (Table 3 and Fig. 4). The significant correlations of GA with FL (r = 0.905) and CRL (r = 0. 997) indicate that in addition to CRL, fetal femor length can be considered one of the estimators of gestational age. Yeh et al. (14) have previously studied femur length and its relationship to GA by ultrasonography. They suggested that there is a strong correlation between femur length and GA. Queenan et al. (24) have already studied the relationship between femur length and GA;

Table 1. Means, standard deviations, t and p values for the femur parameters – gender comparative results of the second trimester fetuses (mm).

Parameter	Females (n = 18)	Males (n = 18)	t	P
HTD	8.23 ± 1.11	7.81 ± 1.03	1.17	0.249
HVD	8.18 ± 1.19	7.74 ± 1.12	1.14	0.261
NVD	6.54 ± 1.04	6.52 ± 1.14	0.03	0.973
GTHVD	10.77 ± 1.59	10.45 ± 1.48	0.61	0.547
MSTD	3.98 ± 0.56	3.99 ± 0.66	0.06	0.952
FL	52.43 ± 5.22	50.74 ± 6.13	0.89	0.380
HVMCL	55.85 ± 5.80	53.96 ± 6.46	0.92	0.362
DB	14.92 ±1.64	14.78 ± 2.10	0.22	0.826

Table 2. Means, standard deviations, t and P values for the femur parameters – gender comparative results of the third trimester fetuses (mm).

Parameter	Females (n = 12)	Males (n = 12)	t	P
HTD	11.47 ± 0.78	11.19 ± 1.23	0.67	0.510
HVD	11.65 ± 0.72	11.19 ± 1.18	1.15	0.264
NVD	9.07 ± 0.81	8.67 ± 0.70	1.30	0.207
GTHVD	14.99 ± 1.39	14.94 ± 1.45	0.85	0.933
MSTD	5.01 ± 0.45	5.18 ± 0.47	0.91	0.375
FL	72.02 ± 3.80	71.68 ± 4.31	0.20	0.843
HVMCL	74.26 ± 3.06	73.35 ± 5.38	0.51	0.615
DB	20.83 ± 1.40	20.81 ± 1.83	0.04	0.970

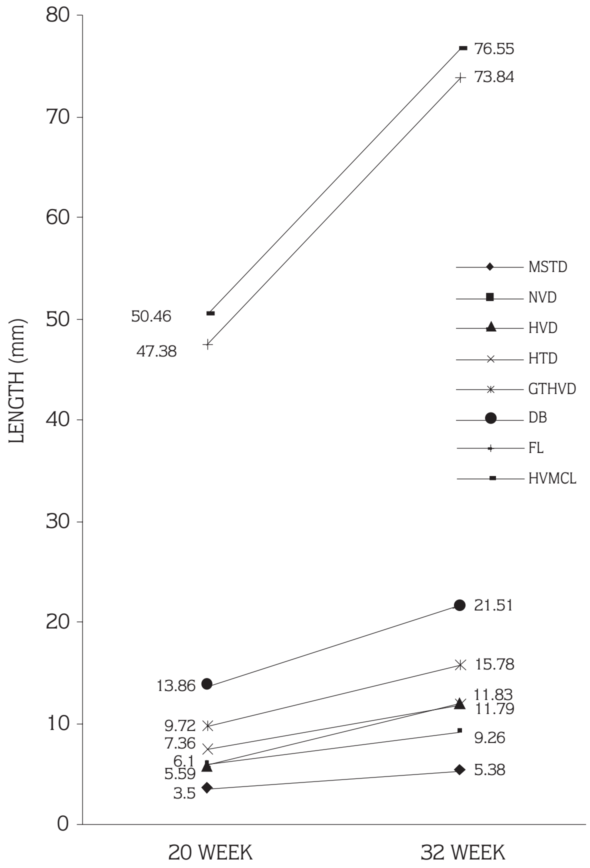

Figure 3. Means of the studied linear measurements at 20 and 32 weeks of gestation (graphical comparison of linear growth rates).

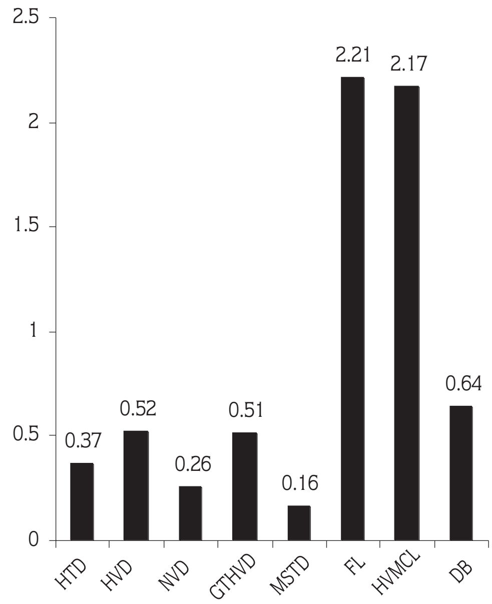

Figure 4. Values of the approximate growth average per week assessed in every parameter.

Table 3. Correlation coefficients (r) between crown-rump length and femur parameters and with the gestational age (week).

	DB	HVMCL	FL	MSTD	GTHVD	NVD	HVD	HTD	GA (wk)
CRL	0.840	0.894	0.906	0.808	0.891	0.772	0.859	0.861	0.997
GA(wk)	0.833	0.886	0.905	0.793	0.891	0.768	0.851	0.853	
HTD	0.955	0.969	0.928	0.882	0.905	0.942	0.989		
HVD	0.951	0.971	0.927	0.883	0.909	0.938			
NVD	0.955	0.934	0.900	0.902	0.878				
GTHVD	0.898	0.924	0.911	0.858					
MSTD	0.898	0.898	0.858						
FL	0.935	0.962							
HVMCL	0.963								

All correlations were significant at the P = 0.01 level

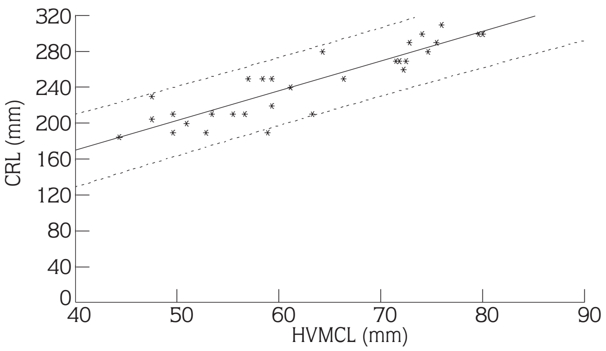

Figure 5. Graph of CRL and HVMCL of study specimens with 95% confidence intervals.

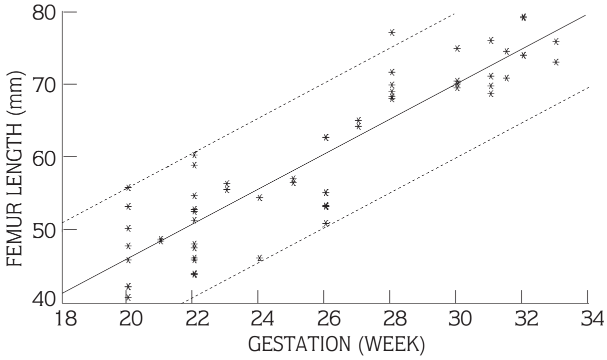

Figure 6. Femoral length related to gestational age with 95% confidence intervals.

they stated that with ultrasonic determination of femur length, the gestational age can be calculated and determined. In Britain, a size chart for fetal femur length taking into consideration the increasing variability with increasing gestational age has been constructed by Chitty et al. (25). Regarding this case, it is believed that the published data were largely different due to methodological differences. As expected, differences between our data and a previous published data set involving ultrasound measurements of FL could be easily distinguished due to differences in the methods of evaluation. The ultrasonic evaluations of FL were in fact carried out on the ossified femur diaphysis and not on the entire length of the femur including the proximal and distal epiphyses as they undergo postnatal ossification; this explains why in some of the published data on ultrasonic measurements, the FL was referred to as "femur diaphysis length". A comparison between our data from immature and premature delivered dead fetuses and previous constructed charts on the suggested ideal FL measurements in relation with predicted gestational age per week (13,15,19,25) indicated that a range of difference between 12.5 and 15.1 mm was found at 20–32 weeks of gestation compared to the same gestational distributions in the charts favorable to our studied specimens. Logically, these differences were a result of invisible epiphyses in the ultrasound femur measurements not being considered. Racial differences in the population should not be neglected; however, we felt it was more appropriate to use a heterogeneous population rather than to distinguish separate racial groups. This should result in a more universally applicable growth curve (19). We recommend that a conformable size chart for fetal parameters be constructed for the Turkish population with a large number of study specimens. While CRL can be used in the determination of the GA of the fetus (2,4), this standard was found to be accurate in assessing GA in the first trimester (13,24,26). In the present study, the strong associations of the different femoral growth parameters CRL and GA show the importance of these fetal measurements in the assessment of GA, and it might be widely applicable in forensic cases and for investigation purposes. We conclude that the measurement of fetal femur length can be considered one of the reliable methods for assessing gestational age.

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