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The Development of the Extremities of Turkish Fetuses During the Fetal Period

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Abstract
Objective: It was aimed to obtain normal morphometric values of the development of foot and its morphology.
Materials and Methods: This study was performed the Anatomy Department of Meram Medical Faculty, at Necmettin Erbakan University between 2006 and 2007. 107 (male 50, female 57) human fetuses who had no external anomaly or pathology and whose ages were 6-37 weeks were included in the study. Fetuses were divided into three groups as trimesters. The length of foot, bimalleolar width, bimalleolar circumference, tarsal height, tarsal circumference, metatarsophalangeal width and metatarsophalangeal circumference were measured.
Results: It was shown that all measurements of foots are significantly different across groups (all $p<0.001$). However, there were no significant differences between the genders for all foot measurements ($p>0.05$). There was a significant positive correlation between the gestational age and the mesurements of foots ($p<0.001$).
Conclusion: The statistically significant correlation between the measurements of foot length suggests that it is a proper determiner of age. We think that these measurements can be helpful in determining gestational ages in fields such as anatomy, pathologic anatomy (fetopathology), obstetric screening and pediatrics.

Keywords: fetus, foot, morphometry

Introduction

In a six-week-old embryo, being flattened, the ends of the extremity buds form the plaques of hands and feet. These plaques are separated from further proximal segments with a circular constriction [1]. The latter constriction divides the proximal part into two and thus two main parts of the extremity become prominent. Due to the death of the cells formed in the apical ectodermic swollen area, this part is divided into five pieces and, therefore the first step is taken to form the fingers of feet and hands. Later the development of fingers is completed with the development of the five segments under the effect of ectoderm proceeding to the end, the formation of cartilage finger framework with the density of mesenchyme, and the necrosed tissues between these five long thin segments [1].

The development process of upper and lower extremities is nearly similar to each other. However, lower extremities achieve the same morphogenetic stages about1-2 days later. In addition to this delay, upper and lower extremities rotate in opposite direction in the 7th week of the gestation [1]. While extensor muscles locate laterally and posteriorly, and thumb locates laterally with a 90^0 bilateral rotation of upper extremity, extensor muscles locate anteriorly and the toe locates medially with a 90^0 medial rotation [1].

Fetal ultrasonography (USG) is used to find out about the fetal health [2]. It is implied that embryogenesis, organogenesis and fetal anatomy should be found out for every gestation week separately for fetal USG, and stated that fetal health should be studied morphometrically as fetus has a developing anatomic and physiologic feature [2].

All structural parameters related to fetus can be used during the fetal development. Gestational age can be determined by measuring the height of the fetus in the early gestational period. Fetal weight can be established with biparietal diameter, head circumference, abdomen circumference, femur length, foot sizes after 14th week. Obtaining normal parameters according to the gestational ages helps each society to determine its normal values for its own patient population and to establish its fetal growth curve. In recent years, the correlations between multi-parameters have been used rather than a single parameter [2]. It was aimed to investigate the developmental stages of the foot during the fetal period morphometrically.

Materials and methods

This study was carried out using the collection of spontaneous aborted fetuses existed in our anatomy laboratory in 2006-2007. This study was approved by the ethical committee (2008/170) of Meram Medical Faculty. We studied on 107 fetuses (50 male, 57 female) with no morphologic malformation and preserved in 10% formalin. The ages of the fetuses were determined as weekly according to Crown Rump Length (CRL). Fetuses were divided into three groups as trimesters. The measurements were obtained with a digital compass sensitive to 0.01mm. The measurements were performed by the same person in order to minimize the possible errors.

The parameters used for evaluating (Figure 1a, b)

Foot length (FL): The distance between the hindmost point of the heel and the tip of the 1st or 2nd finger (which is longer).
Bimalleolar width (BMW): The distance between the

innermost point of malleolus medial of os tibia and the outermost point of malleolus lateral of os fibula.

Bimalleolar circumference (BMC): The length of circumference obtained from between the malleolus medial of os tibia and malleolus lateral of os fibula.

Tarsal height (TH): The distance between the plantar pedis and dorsum pedis 1cm back to the half of the foot length.

Tarsal circumference (TC): The length of the circumference obtained vertically from the point where tarsal height was measured to the axle of foot length.

Metatarsofalangeal width (MTFW): The distance between the innermost point of the head of 1st metatarsal and the outermost point of the head 5th metatarsal.

Metatarsophalangeal circumference (MTFC): The length of circumference passing through the metatarsophalangeal width points.

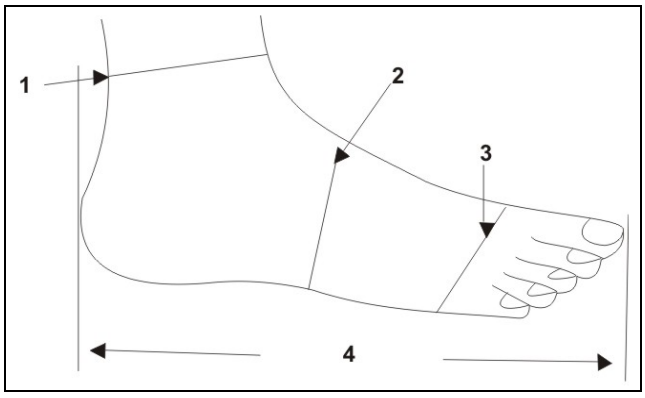

Fig 1a: Foot measurements with figures (1) Bimalleolar width, (2) Tarsal height, (3) Metatarsophalangeal width, (4) Foot length

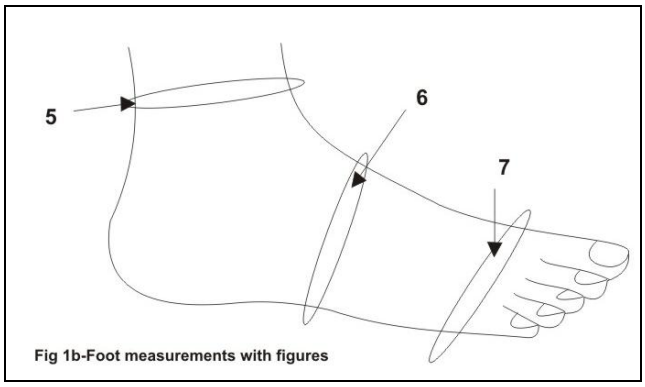

Fig 1b: Foot measurements with figures (1) Bimalleolar circumference, (2) Tarsal circumference, (3) Metatarsophalangeal circumference

Statistical Evaluation

The measurements belonging to foot of fetuses were assigned to MS Excel program and data were checked twice. All analyses were performed by SPSS 19.0 (IBM Incorp., Chicago, IL) software. The variables were presented as frequencies and percentages for categorical variables, mean±SD for numerical variables. Continious variables were detected for normality by Kolmogorov-Smirnov test. Many of the variables were not distributed normally and some variables had a overdispersion. Therefore non-parametric methods were used for comparing groups. Mann-Whitney U test was used for two independent groups and Kruskal-Wallis test was used for several groups with post-hoc tests. Spearman's Rho correlation analysis was used to see the relation between gestational age and extremity measurements. $p<0.05$ value was considered statistically significant taking type-I error as 5%.

Results

We measured total of seven distances for foot on 107 fetuses. Nearly half of the fetuses were female (53.3%; n=57). Most of the fetuses were in 2nd trimester period (66.4%; n=71). The number of fetuses on 3rd trimester period (18.7%) was greater than 1st trimester period (15%). Gestational ages were ranging 6 week to 37 week. According to the weeks, trimester periods were determined. In gesttional age of 13 week, there was 13 fetuses (12.1%). The descriptive statistics of foot measurements of fetuses can be seen in Table 1. The minimum values for tarsal height, bimalleolar width and circumference and metatarso phalangeal circumerence were equal and 1 mm. Bimalleolar and tarsal circumferences reached up to 98 and 95 mm respectively.

All measurements belonging to foot development in fetuses were compared according to trimester groups. The descriptive statistics can be seen in Table 2 with *p* values. It was shown that all measurements of foots are significantly different across groups (all $p<0.001$). Moreover, the pairwise comparisons were significant across all trimester groups. All foot measurements were compared according to gender of fetuses. However, there were no significant differences between the genders for all foot measurements ($p>0.05$). The descriptive statistics for gender groups can be seen in Table 3. In all measurements except for metatarso phalangeal circumference, the mean values of foots were in males greater than females.

Table 1: Descriptive statistics of foot mesurements of fetuses.

Parameters		Minimum	Maximum	Mean	SD
FL	*mm*	7.40	78.00	34.77	17.04
BMW	*mm*	1.70	29.30	9.91	5.47
BMC	*mm*	1.00	98.00	27.54	22.50
TH	*mm*	1.00	25.90	8.64	4.89
TC	*mm*	2.00	95.00	31.11	22.00
MTFW	*mm*	2.20	34.40	13.48	7.37
MTPC	*mm*	1.00	43.00	30.42	46.03

Table 2: Descriptive statistics of foot mesurements according to trimester periods.

Parameters		1st Trimester (n=16)	2nd Trimester (n=71)	3rd Trimester (n=20)	*p*
FL	*mm*	13.92±5.38	32.03±10.08	61.17±9.80	*<0.001**
BMW	*mm*	3.86±1.50	8.86±3.07	18.47±4.32	*<0.001**
BMC	*mm*	8.50±10.56	26.87±16.38	45.15±33.37	*<0.001**
TH	*mm*	3.10±1.26	7.72±2.75	16.32±3.68	*<0.001**

TC	*mm*	10.19±10.35	30.21±16.29	51.06±29.13	*<0.001**
MTFW	*mm*	5.19±2.30	12.04±4.11	25.23±5.08	*<0.001**
MTFC	*mm*	8.13±10.14	31.69±52.21	43.75±32.92	*<0.001**

Table 3: Descriptive statistics of foot mesurements according to gender.

Extremity		Male (n=50)	Female (n=57)	*p*
FL	*mm*	38.42±18.97	31.56±14.58	*0.102*
BMW	*mm*	10.92±6.38	9.02±4.41	*0.328*
BMC	*mm*	30.58±25.06	24.88±19.83	*0.349*
TH	*mm*	9.58±5.54	7.81±4.12	*0.171*
TC	*mm*	34.56±24.24	28.08±19.55	*0.268*
MTFW	*mm*	15.06±8.45	12.10±6.02	*0.155*
MTFC	*mm*	29.39±24.60	31.32±58.98	*0.373*

The descriptive statistics were calculated according to gestational age and presented in Table 4. There was a significant positive correlation between the gestational age and the mesurements of foots (p<0.001). The lowest correlation coefficient belonged to metatarso phalangeal circumference (R=56.2%; p<0.001), and foot length measure had the highest correlation value (R=0.936; p<0.001). All correlation coefficients can be seen in Table 5.

Table 4: Descriptive statistics of foot mesurements according to gestational age

Gestational Age (week)	FL	BW	BC	TH	TC	MW	MC
6 (n=1)	8.5±0	2.2±0	1±0	2.4±0	2.4±0	3±0	1±0
8 (n=1)	7.4±0	2.2±0	1±0	1.5±0	2.2±0	2.2±0	1.5±0
9 (n=2)	8.55±0.21	2±0.42	1.25±0.35	1.5±0.71	2.7±0.99	2.9±0.14	1±0
10 (n=2)	10.45±0.64	3.25±0.35	1.5±0	2.8±0.85	3.4±0.42	4±0	1.5±0
11 (n=2)	14.3±2.69	4.9±1.13	13±15.56	2.9±0.42	14.5±13.44	5.1±0.99	12±14.14
12 (n=8)	17.53±4.91	4.63±1.31	12.81±11.5	3.91±1.11	14.66±11.34	6.74±2.14	12.31±11.26
13 (n=13)	22.28±10.32	5.86±2.97	25.27±13.07	5.42±2.91	24.66±13.06	7.75±2.41	21.69±10.88
14 (n=8)	22.95±2.27	6.11±0.97	17.44±12.16	4.53±0.58	18.8±10.35	8.23±0.54	16.31±11.46
15 (n=5)	26.98±1.98	7.32±1.04	19.9±14.98	6.88±0.89	21.14±10.35	11.08±1.04	17.2±12.71
16 (n=8)	31.69±8.49	9.95±3.51	32.5±18.29	8.64±3.73	37±17.7	12.86±3.66	81.44±146.91
17 (n=9)	31.61±2.99	9.13±1.21	22.67±14.67	7.76±1.26	26.32±12.88	11.36±1.26	21.94±14.37
18 (n=6)	31.55±4.12	8.98±2.47	13.5±15.52	8.12±1.83	19.8±15.05	11.64±1.66	14.08±17.4
19 (n=5)	39.06±0.99	10.76±1.49	32.2±15.97	9.86±0.63	37.9±15.13	14.94±1.39	34.2±17.01
20 (n=6)	42.47±5.7	11.48±2.05	43.33±3.14	10.28±2.24	47.5±3.62	15.95±1.6	43.83±4.49
21 (n=2)	46.75±3.46	11.9±1.56	22±25.46	8.55±0.49	27.85±20.01	17.85±3.04	21.5±23.33
22 (n=6)	42.93±4.1	11.1±2.12	41.5±19.53	10.3±1.43	46.22±19.29	17.23±4.52	42±20.57
23 (n=3)	44.43±9.23	14.2±3.25	49±10.58	11.57±0.93	55.33±10.02	18.73±6.01	48.33±13.32
24 (n=1)	53.8±0	14±0	4.5±0	10.4±0	12.8±0	13.7±0	4±0
25 (n=4)	50.55±5	15.9±1.69	6.13±0.63	13.48±1.74	15.48±2.23	20.35±2.58	5.63±0.75
27 (n=2)	60.55±2.76	14.9±2.55	61±12.73	14.9±2.83	62.5±17.68	22.4±3.68	61.5±16.26
28 (n=5)	57.24±2.01	15.48±1.48	63.4±4.22	14.72±1.65	65±7.91	23.62±3.66	62.2±6.46
30 (n=2)	70.9±5.8	22.75±0.49	45.5±53.03	18.4±3.68	60.5±48.79	33.2±1.7	48.75±58.34
32 (n=2)	62.5±10.61	18.4±3.39	36.25±40.66	14.5±0.71	42.7±31.54	26.7±2.83	33.75±37.12
33 (n=2)	71.7±3.96	22.05±0.49	9±1.41	19.9±0	22.9±0.42	28.15±5.3	7.75±1.06
35 (n=1)	78±0	25±0	90±0	22±0	95±0	31±0	85±0
37 (n=1)	75.7±0	29.3±0	98±0	25.9±0	92±0	31.8±0	93±0

Table 5: Spearman's Rho correlation values between gestational age and foot measurements

Gestational Age (week)	FL	BW	BC	TH	TC	MW	MC
Rho	0.936	0.904	0.572	0.901	0.591	0.927	0.562
p	*<0.001**	*<0.001**	*<0.001**	*<0.001**	*<0.001**	*<0.001**	*<0.001**

Discussion

This study was carried out on total 107 fetus cadavers (57 female and 50 male) aged between 7 and 37 weeks. We studied total 107 feet. The length, width and circumference of the feet were obtained. Then statistical studies which are thought to give ideas about the development anatomy of the foot were performed.

In our study, significant correlation between gestational age and foot sizes (at least r: 0.85, p‹0.001) was determined when the whole fetal period was taken into consideration which is compatible with other studies in which some parameters such as CRL, weight, bone length, biparietal diameter were used and suggested as an alternative that arm, forearm, hand and foot lengths could also be used to determine the gestational age [3, 4].

After Streeter first evaluated the fetal foot for menstrual age

assessment in 1920, little was written until 1984, when Hern' s elaborate study demonstrated a strong relationship between the fetal foot the gestational age. In that study, the biparietal diameter of the specimen was shown to correlate well with ultrasound measurements of the biparietal diameter. Unfortunately, at the time of Hern's ual study, little had been written about the use of either long bones of the fetal foot to estimate menstrage.

As more biologic parameters are described to assess menstrual age, their accuracy as predictors has become more reliable. İn addition, the use of these documened relationships, with their high correlations, can aid us clinically in describing the normal or abnormal fetus. Use of the descriptive relationship between the fetal foot and the other fetal structures evaluated in this paper should further aid in evaluating the fetus [6]. We are currently studying interrelationships between the fetal foot and other structural measurements in the third trimester and determining whether the addition of the fetal foot improves the accuracy of menstrual age assessment, either as an individual measurement or in a weighted combination of measurements for the assessment of a mean ultrasound age, as suggested by hadlock *et al.* [7].

İt is still controversial whether there is a significant difference in fetal extremity morphology among fetuses of different ethnic origins in the first trimester [8]. Hata *et al.* [9] may reflected in the curve ethnic characteristics i.e. fetal growth in German fetuses may be more than that in Japanese fetuses at the end of third trimester [10].

In their postmortem evaluations of fetal foot length, Hern [5] and Munsick [2] have described the relationship between the fetal foot and gestational age as a curvilinear association, based on regression analysis, the evaluation of central tendency, and visual inspection of the data points.

There was significant difference in the values of length, width and circumference of the foot between the sexes, lower values were determined in the parameters of female fetuses. While there are compared results in the literature, there was significant statistical morphometric differences between the sexes. For example: Tarsal height was 9.58 ± 5.54 mm in males and 7.81 ± 4.12 mm in females, metatarsophalangeal circumference was 29.39 ± 24.60 mm in males and 31.32 ± 58.98 mm in females.

We established a significant correlation between the foot length and gestational week in our study. The measurements of foot lengths obtained from the 7-37 week-old fetuses we investigated in this study are compatible with other studies [6, 10, 11, 12, 13, 14, 15].

As a result of this study; the structure of human fetuses and general morphologic features and morphometric evaluation with variations of the fetuses included in the study were obtained. It was agreed that the materials used in this study were morphologically normal. However, both the factors affecting intrauterine growth period and negative factors causing abortus should not be ignored.

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