The Morphometric Development Of The Fetal Knee During The Fetal Period

Fetal Dönemde Fetal Dizin Morfometrik Gelişimi

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ABSTRACT

Aim: The study aims at examining morphometric growth patterns of the distal part of the femur, the proximal part of the tibia, the patella,and anterior and posterior cruciate ligaments in human fetal knee.

Method: This study was conducted at Meram Faculty of Medicine, Anatomy Department in 2009. The fetuses were obtained from Selcuk University, Meram Faculty of Medicine the Gynaecology Department, and Dr. Faruk Sükan Maternity Hospital (Konya, Turkey). Fifty spontaneously aborted fetuses with ages ranging between 9 and 37 weeks of gestation (24 male right, 24 male left, 26 female right and 26 female left) that have no evident malformations were analyzed. The measurements of dimensions of the distal part of the femur, the proximal part of the tibia, the patella, the anterior and posterior cruciate ligaments were carried out. A characterization of the aspect ratio (the medial-lateral to anterior-posterior dimensions) was performed for the proximal aspect of the tibia and the distal part of the femur. Student's T test was used for Statistical analysis of comparisons.

Results: In all measurements, no gender and side differences were detected (p> 0,05) and no differences were observed in the femur aspect ratio, tibia aspect ratio between males and females (p>0,05) On the contrary, a significant relationship was seen between trimesters and all parameters (p<0.005).

Conclusion: Thorough information of knee joint and its components regarding the fetal period will reveal the extent of biological variation of knee joint and its components that will be used in future studies. We expect that the data obtained in this study will be beneficial for other studies on knee anomalies, pathologies and variations in addition to diagnoses and treatments of such conditions conducted in obstetrics, perinatology, forensic medicine and fetal pathology departments.

Key words: Knee, Human fetuses, Morphometry, Anatomy

ÖZET

Amaç: Bu çalışma, femurun distal kısmının, tibianın proksimal kısmının, patella ve insan fetal dizindeki ön ve arka çapraz bağların morfometrik büyüme modellerini incelemeyi amaçlamaktadır.

Yöntem: Bu çalışma 2009 yılında Meram Tıp Fakültesi Anatomi Anabilim Dalı'nda yapılmıştır. Fetuslar; Selçuk Üniversitesi, Meram Tıp Fakültesi Kadın Hastalıkları Anabilim Dalı ve Dr. Faruk Sükan Kadın Doğum Hastanesi'nden (Konya, Türkiye) alınmıştır. Belirgin malformasyonları olmayan, yaşları 9 ila 37 hafta arasında değişen, kendiliğinden düşen 50 fetüs (24 erkek sağ, 24 erkek sol, 26 kadın sağ ve 26 kadın sol) analiz edilmiştir. Femurun distal kısmının, tibianın proksimal kısmının, patella, ön ve arka çapraz bağların boyutlarının ölçümü yapılmıştır. Tibia'nın proksimal yönü ve femurun distal kısmı için en boy oranının bir karakterizasyonu (medial-lateralden anterior-posterior boyutlara) yapılmıştır. Karşılaştırmaların istatistiksel analizi için Student's T testi kullanılmıştır.

Bulgular: Ölçümlerde cinsiyet ve kenar farkı saptanmamıştır (p>0,05) ve erkek ve kadınlar arasında femur en-boy oranında, tibia en-boy oranında fark gözlenmemiştir (p>0,05). Aksine, trimesterler ve tüm parametreler arasında anlamlı bir ilişki saptanmıştır (p<0.005).

Sonuç: Diz eklemi ve bileşenlerinin fetal döneme ilişkin kapsamlı bilgileri, ileriki çalışmalarda kullanılacak olan diz ekleminin bileşenlerinin biyolojik varyasyonunun derecesini ortaya çıkaracaktır. Bu çalışmada elde edilen verilerin, obtetri, perinatoloji, adli tıp ve fetal patoloji bölümlerinde yürütülen bu tür durumların tanı ve tedavilerine ek olarak diz anomalileri, patolojiler ve varyasyonlar ile ilgili yapılacak diğer çalışmalar için yararlı olacağını umuyoruz.

Anahtar kelimeler: Diz, İnsan Fetusları, Morfometri, Anatomi

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1. INTRODUCTION

Knee-joint is the biggest joint in the body. The cartilage, ligaments and capsule elements of the joint develop in the gaps of the central mesenchyme concentration building the long bones of the extremities. This central layer of ligament tissues forms the interior elements of the joint. Concentrating proximally and distally, they produce the synovia that later covers the joint gap. Meniscus and closed joint ligaments are formed by the central zone (i.e; cruciate knee ligaments) (Moore 1993:95; Sadler 1990:229).

In the early stages of pregnancy, the detection of congenital anomalies emerged from external causes such as genetic diseases, intrauterine infections and teratogenic agents is critical for prenatal diagnosis. Following the fetal development involves all structural parameters of the fetus. Fetal growth curves can be formed for parametric evaluations according to fetal age for all ethnic groups and may set the normal standards of the fetal growth of a population. Both invasive and non-invasive techniques are used for prenatal diagnosis. Fetal ultrasonography (USG) mostly used as non-invasive procedure has the benefit of demonstrating all fetal formations. In order to evaluate all stages of embryogenesis via USG, fetal morphometric anatomy should be known for every week of gestation.

Fetal femur length has been one of the standards employed as a morphometric evaluation of fetal development in second and third trimester fetuses. Crown rump length (Ziylan-Murshid 2003:30; McBride, et al. 1984:188; Hesinger 1992:1690; Dubowite, et al. 1970:4; Singer, et al. 1991:14-18), biparietal diameter, head and body circumference and cephalic index standards were used for the same purpose (Kurtz, et al. 1980:321; Hadlock, et al.1982a:359; Seeds-Gofalo1982:682). Skeletal growth disturbances (O'Brien-Queenan 1982:37; Qeenan 1980:299; Abramowicz, et al. 1989:1139; Bromley et al.,1993:450; Deter et al.,1981:483), estimation of fetal gestational age (Seeds-Gofalo 1982:683; Hadlock, et al.1982b:877; Yeh, et al. 1982:520; Shalev, et al. 1985:72), developmental abnormality and identification of certain fetal congenital anomalies (McBride, et al. 1984:189; Biaglotti, et al. 1990:187; Shah, et al. 1990:187), and detection of population growth features (Deter, et al. 1987:301; O'Brien-Queenan 1981:835) were the goals of various studies. Graphs were created on the correlation of fetal growth with gestational age (Shepard, et al. 1964:125; Iffy, et al.1975:175) and the relationship between body and organ weight (Tanimura, et al. 1971:230).

Comprehensive morphological data on the patella and the patellar ligament are crucial to understand the normal mechanics of the knee joint, pathogenesis of disorders involving the knee, and surgical management, including reconstructive procedures (Koyuncu, et al. 2011:227; Miller, et al. 1996:340; Yoo, et al. 2007:625). The anatomical position of the patella is a critical factor in the natural history of disorders of the patellofemoral joint (Schlenzka-Schwesinger 1990:20; Andrikoula, et al. 2006:215; White-Sherman 2009:24). An abnormally superior patellar position may lead to pain owing to either patellar instability or because a patellar with chondromalacia may create abnormal contact stress (Biedert-Albrecht 2006:710). The patella may have diverse shapes, some of which are associated with patellar instability. Previous studies suggested that morphological differences such as a narrow medial articular surface of the patella have a function in the pathogenesis of certain pathologies (Biedert-Albrecht 2006:710; Fucentese, et al. 2006:147).

Moreover, morphological and morphometric features of certain bones display gender differences (Introna, et al. 2005:41; Scheuer 2002:190; Mahfouz 2007:162). As a result of analyzing both the patella and patellar ligament in adults, they were identified to exhibit such differences (Miller, et al. 1996:340; Yoo, et al. 2007:627; Biedert-Albrecht 2006:709; Introna, et al. 2005:41; Mahfouz, et al. 2007:165; Greisamer-Meadows 1992:173). These data are fundamental to completely understand knee biomechanics and may be connected to forensic science and anthropology (Mahfouz, et al. 2007:166; Kemkes-Grottenthaler 2005:131).

The purpose of this study was to establish the normal dimensions of the distal part of the femur, the proximal part of the tibia, the patella and the anterior and posterior cruciate ligaments of the knee in human fetuses.

2.METHODS:

This study was carried out on spontaneously aborted 50 fetuses (24 males and 26 females) (6 first trimester, 31 second trimester and 13 third trimester) with no observable congenital malformations or maternal history of risky prepnancy. The fetuses were obtained from Selcuk University, Meram Faculty of Medicine, Gynaecology Department, and Dr. Faruk Sükan Maternity Hospital (Konya,Turkey) between 2005 and 2010. The ages of the fetuses were determined to be between the 11th and 37th postmenstrual weeks depending on the crown-rump length (CRL) measurements (Hesinger 1992:1690).Written consent from the families and an approval from the Ethics Board of Necmettin Erbakan University, Meram Faculty of Medicine were received before the study began. The cases were classified according to gestational age: Group 1 (1st trimester), Group 2 (2nd trimester) and Group 3 (3 rd trimester) consisted of fetuses whose gestational ages were less than 12 weeks, between 13 to 25 weeks, and between 26 to 37 weeks, respectively. The cases that have an anomaly or pathology of the distal part of the femur,the proximal part of the tibia,the patella and anterior and posterior cruciate ligaments were not involved in the study. The tools such as caliper, measuring tape, plastic ruler or compass were used for the measurements. The immersion technique was used to fix the fetuses in %10 formalin. In the knee region, the skin, regional surrounding soft tissues and the upper end of the muscle tibialis anterior m, and the lower ends of the muscules quadriceps femoris m, sartorius m, gracilis m were fully removed. Patellar ligament, lateral collateral ligament, medial collateral ligament, arcuate popliteal ligament, oblique popliteal ligament were taken apart and analyzed under the microscope. Then, the lower end of quadriceps femoris m left its place was pulled anteriorely to some extent and hence, the exposed part of the capsule clinging to the femur was isolated from the bone. In the end, when the lower end of quadriceps femoris m, patella and patellar ligament were laid anteriorly altogether, joint gap was accessible. In this gap, it was easy to see anterior and posterior cruciate ligaments that cross each other in the space between the condyles of the femur.

Measurements were obtained from each knee (Figs 1-7) in order to enable comparatively slight changes after keeping in formalin.

Parameters for femur are as follows;

<u>Proximal breath:</u>

The distance between superior margins of lateral and medial condylus (A).

<u>Distal breath:</u>

The maximal distance between external margins of lateral and medial condylus (B).

<u>Maximal breath:</u>

The distance between external margins of inferior articular surface of lateral and medial condylus (C).

The maximum width of the intercondyler notch (D)

The maximal height of the lateral condylus (G)

The maximal height of the medial condylus (H)

For Tibia

The maximal antero-posterior width of the condylus lateralis (K)

The maximal antero-posterior width of the condylus medialis (J)

The maximal distance between external margins of lateral and medial condylus (I)

The maximal antero-posterior width of the median line (T)

For Patella

The maximal transverse width (M)

The maximal vertical height (N)

The thickness of the patella (L)

For Lig Cruciatum Anterior

The length of the anterior cruciate ligament (LACL)

The thickness of anterior cruciate ligament (TACL)

For Lig Cruciatum Posterior

The length of the posterior cruciate ligament (LCPL)

The thickness of posterior cruciate ligament (TPCL)

A characterization of the aspect ratio (the medial lateral-dimension divided by the anterior

posterior dimensionx100) was performed for the tibia and femur.

The measured data were analyzed through using Student t-test (Statistical Package for Social Sciences Version 10.0 for Windows-software) in relation to gender and trimester. The difference between these groups reached a significant p value of less than 0.05. The results were presented as the mean ± standart deviation in tables.

FAR: Femur aspect ratio

TAR: Tibia aspect ratio

3. RESULTS

After dissecting the knee and reaching the femur, tibia and patella, they were checked for any gross anomaly; then, the location of the knee and their connection with surrounding structures were identified. There were no pathologies in the tibialis posterior m, quadriceps femoris m, sartorius m, gracilis m and they were all in their usual position.

In a preliminary study, the parameters of interest were measured in 10 cases by three researchers. Each researcher was blind to the others' measurement. Student's t test was used to compare the results of each rater. There were no significant differences between the measurements ($p>0.05$). Pearson's correlation test was also used to compare the results of raters and significant correlations were observed between each rater (0.001). All the measurements of the actual study were carried out by a single researcher.

No differences were identified in general external features between genders ($p>0.05$). Number of cases and means of the measurements related to gender are shown in Table 1. Gender or laterality differences were not observed in knee joint, the distal part of the femur, the proximal part of the tibia and the patella separate for both knee joints ($p>0.05$). Means of parameters and standard deviation of the parameters of the trimesters are presented in Table 2. A significant relation was found between all parameters and trimesters ($p<0.001$).

The means of femur aspect ratio and tibia aspect ratio were detected from the right and left knee joints. Separate femur aspect ratio and tibia aspect ratio for both knee joints showed differences in gender and laterality ($p<0.005$). Femur aspect ratio was found to be larger on the right in females than in males, and larger on the left in males than females. In contrast, the tibia aspect ratio was larger on the right in males than females, and larger on the left in females than males (Table 1, Table 2). A significant relationship was identified between femur aspect ratio, tibia aspect ratio and trimesters ($p<0.05$) (Table2).

In our study, positive correlations were observed between general external features (BPD, CRL, and femur and foot lengths) that were signs of gestational age and knee joints parameters ($p<0.05$) (Table 2).

Table 1: The descriptive statistics of measurements of both sides according to gender

	Right			Left		
	Male (n=24)	Female (n=26)		Male (n=24)	Female (n=26)	
	Mean±SD		p	Mean±SD		p
A	7,78±3,56	7,35±2,75	*0,631*	7,41±3,38	7,17±2,72	*0,789*
B	14,76±6,68	14,22±5,03	*0,748*	14,58±7,03	14,19±5,08	*0,820*
C	13,86±5,75	13,95±4,82	*0,954*	14,32±6,08	13,88±4,43	*0,774*
D	6,54±2,25	6,38±2,06	*0,795*	6,47±2,41	6,20±2,15	*0,677*
G	10,62±4,62	10,07±3,2	*0,621*	10,34±4,81	10,35±3,63	*0,992*
H	9,72±4,22	9,44±3,26	*0,795*	10,00±4,75	10,08±3,47	*0,945*
J	8,49±3,76	8,53±2,96	*0,798*	7,90±3,45	8,27±3,18	*0,702*
I	14,56±6,76	14,28±4,99	*0,867*	14,85±7,00	14,63±5,00	*0,900*
K	7,90±3,42	7,67±2,63	*0,793*	7,76±3,50	8,09±3,05	*0,726*
T	7,69±3,11	8,11±3,03	*0,630*	7,93±3,81	7,92±2,95	*0,985*
L	3,06±1,89	2,93±1,45	*0,790*	3,37±1,82	3,30±1,29	*0,874*
M	8,89±3,78	8,80±3,02	*0,925*	8,50±3,67	8,65±2,70	*0,862*
N	7,44±3,06	7,57±2,44	*0,865*	7,32±2,88	7,39±2,12	*0,925*
LACL	4,39±2,18	4,65±1,75	*0,643*	4,85±2,37	5,40±2,05	*0,387*
TACL	2,17±0,93	1,80±0,62	*0,109*	2,35±1,03	2,65±0,88	*0,271*
LPCL	4,92±2,32	5,20±2,16	*0,657*	4,68±2,49	4,74±1,77	*0,918*
TPCL	2,29±1,01	2,48±0,93	*0,487*	2,39±1,12	2,48±0,86	*0,753*
FAR	144,62±19,43	150,89±15,99	*0,217*	145,23±13,58	140,04±13,52	*0,183*
TAR	175,65±37,06	172,11±33,09	*0,723*	186,88±27,46	187,52±26,12	*0,932*

Table 2: The descriptive statistics of measurements of right side according to trimester period

Right				
	1st trimester (n=6)	2nd trimester (n=31)	3rd trimester (n=13)	
	Mean±SD			p
A	3,92±1,38	6,63±2,16	11,46±1,57	***<0,001****
B	7,72±2,52	12,59±3,45	22,11±3,34	***<0,001****
C	8,05±2,26	12,14±3,07	20,83±2,99	***<0,001****
D	4,08±1,35	5,90±1,45	8,90±1,56	***<0,001****
G	6,13±1,41	8,94±2,00	15,58±2,82	***<0,001****
H	5,25±1,65	8,31±2,12	14,58±1,88	***<0,001****
J	5,18±1,18 [a]	7,34±2,22 [a]	12,85±1,75	***<0,001****
I	8,02±2,85	12,7±3,97	21,46±3,85	***<0,001****
K	4,72±1,32 [b]	6,93±2,40 [b]	11,23±1,55	***<0,001****
T	4,35±0,87	7,57±2,54	10,36±2,88	***<0,001****
L	1,43±0,66 [c]	2,34±0,96 [c]	5,27±0,95	***<0,001****
M	4,65±1,56	7,75±1,97	13,38±1,23	***<0,001****
N	4,12±1,43	6,69±1,68	11,02±1,25	***<0,001****
LACL	2,32±0,60	4,08±1,54	6,61±1,37	***<0,001****
TACL	1,38±0,48 [d]	1,82±0,76 [d]	2,63±0,59	***0,001****
LPCL	2,78±1,19	4,33±1,34	7,88±1,56	***<0,001****
TPCL	1,32±0,52	2,14±0,74	3,48±0,53	***<0,001****
FAR	147,85±20,68	146,43±20,66	151,35±5,79	*0,714*
TAR	181,89±39,31	164,86±32,45	191,41±32,78	*0,054*

: significant at 0.05 level in bold characters

[a, b, c, d] superscript letters denote the significance of the pairwise groups.

Table 3: The descriptive statistics of measurements of left side according to trimester period

Left	1st trimester (n=6)	2nd trimester (n=31)	3rd trimester (n=13)	
	Mean±SD			*p*
A	3,70±1,37	6,31±1,91	11,27±1,18	***<0,001****
B	7,10±2,75	12,58±3,75	22,02±3,54	***<0,001****
C	8,12±2,45	12,47±3,35	20,72±3,02	***<0,001****
D	3,70±1,40	5,66±1,49	9,12±1,23	***<0,001****
G	5,88±1,95	9,06±2,98	15,46±2,30	***<0,001****
H	5,82±2,44	8,67±2,59	15,28±2,33	***<0,001****
J	4,23±1,54	7,17±2,31	12,07±1,72	***<0,001****
I	7,92±2,92	12,97±4,16	22,08±3,05	***<0,001****
K	4,50±1,07	6,88±2,17	12,02±1,97	***<0,001****
T	4,50±1,31	6,86±2,33	12,03±2,13	***<0,001****
L	1,65±0,82	2,85±0,92	5,25±1,17	***<0,001****
M	4,75±1,91	7,62±1,98	12,63±1,46	***<0,001****
N	4,77±1,17	6,63±1,64	10,28±1,99	***<0,001****
LACL	2,40±0,96	4,66±1,74	7,55±1,10	***<0,001****
TACL	1,28±0,48	2,35±0,79	3,43±0,58	***<0,001****
LPCL	2,38±0,88	4,22±1,57	6,95±1,77	***<0,001****
TPCL	1,33±0,60	2,19±0,72	3,53±0,68	***<0,001****
FAR	123,18±7,72	145,57±12,77[a]	144,21±10,74[a]	***<0,001****
TAR	174,34±23,65	190,88±23,9	184,42±32,86	*0,348*

***: *significant at 0.05 level in bold characters*
[a] *superscript letter denotes the significance of the pairwise groups.*

Table 4: The comparison between right and left sides

(n=50)	Right	Left	
	Mean±SD		*p*
A	7,56±3,14	7,29±3,03	*0,064*
B	14,48±5,83	14,38±6,04	*0,459*
C	13,91±5,23	14,09±5,24	*0,344*
D	6,46±2,13	6,33±2,26	*0,326*
G	10,33±3,91	10,34±4,19	*0,957*
H	9,58±3,72	10,05±4,09	***0,008****
J	8,51±3,33	8,09±3,28	***0,018****
I	14,42±5,85	14,73±5,98	*0,231*
K	7,78±3,01	7,93±3,24	*0,488*
T	7,91±3,04	7,92±3,35	*0,970*
L	3,00±1,66	3,33±1,55	***0,001****
M	8,84±3,37	8,58±3,17	*0,069*
N	7,51±2,73	7,36±2,49	*0,419*
LACL	4,53±1,96	5,14±2,20	***0,001****
TACL	1,98±0,79	2,51±0,95	***<0,001****
LPCL	5,07±2,22	4,71±2,13	*0,115*
TPCL	2,39±0,97	2,44±0,98	*0,633*
FAR	147,88±17,82	142,53±13,66	*0,104*
TAR	173,81±34,74	187,21±26,5	***0,045****

***: *significant at 0.05 level in bold characters*

Table 5: The correlation between gestational age and all measurements according to trimester periods in males

Male	Gestational age (week)							
	2.trimester (right)		2.trimester (left)		3.trimester (right)		3.trimester (left)	
	Rho	p	Rho	p	Rho	p	Rho	p
A	0,830	<0,001*	0,845	<0,001*	0,440	0,276	0,707	0,050
B	0,983	<0,001*	0,983	<0,001*	0,886	0,003*	0,970	<0,001*
C	0,910	<0,001*	0,981	<0,001*	0,874	0,005*	0,898	0,002*
D	0,760	0,003*	0,934	<0,001*	0,934	0,001*	0,623	0,099
G	0,904	<0,001*	0,934	<0,001*	0,910	0,002*	0,934	0,001*
H	0,954	<0,001*	0,981	<0,001*	0,826	0,011*	0,620	0,101
J	0,964	<0,001*	0,933	<0,001*	0,608	0,109	0,958	<0,001*
I	0,903	<0,001*	0,979	<0,001*	0,874	0,005*	0,970	<0,001*
K	0,911	<0,001*	0,967	<0,001*	0,494	0,213	0,443	0,272
T	0,770	0,002*	0,960	<0,001*	-0,295	0,479	0,455	0,257
L	0,544	0,055*	0,864	<0,001*	0,758	0,029*	0,897	0,003*
M	0,935	<0,001*	0,958	<0,001*	0,813	0,014*	0,790	0,020*
N	0,927	<0,001*	0,849	<0,001*	0,247	0,555	0,527	0,180
LACL	0,701	0,008*	0,914	<0,001*	0,635	0,091	0,458	0,254
TACL	0,592	0,033*	0,854	<0,001*	0,687	0,060	-0,373	0,362
LPCL	0,280	0,355	0,898	<0,001*	0,479	0,230	0,467	0,243
TPCL	0,157	0,609	0,795	0,001*	0,862	0,006*	0,568	0,142
FAR	0,233	0,444	-0,416	0,158	0,766	0,027*	0,683	0,062
TAR	0,357	0,231	-0,014	0,964	0,707	0,050	-0,371	0,365

*: *significant at 0.05 level in bold characters*

Table 6: The correlation between gestational age and all measurements according to trimester periods in females

Female	Gestational age (week)							
	2.trimester (right)		2.trimester (left)		3.trimester (right)		3.trimester (left)	
	Rho	p	Rho	p	Rho	p	Rho	p
A	0,951	<0,001*	0,928	<0,001*	0,667	0,219	-0,553	0,334
B	0,917	<0,001*	0,952	<0,001*	0,718	0,172	-0,500	0,391
C	0,934	<0,001*	0,935	<0,001*	-0,154	0,805	0,500	0,391
D	0,700	0,001*	0,871	<0,001*	0,500	0,391	-0,103	0,870
G	0,894	<0,001*	0,951	<0,001*	0,821	0,089	-0,205	0,741
H	0,898	<0,001*	0,850	<0,001*	0,895	0,040*	0,574	0,312
J	0,845	<0,001*	0,951	<0,001*	0,667	0,219	0,462	0,434
I	0,893	<0,001*	0,940	<0,001*	0,718	0,172	-0,462	0,434
K	0,810	<0,001*	0,915	<0,001*	-0,616	0,269	0,526	0,362
T	0,812	<0,001*	0,953	<0,001*	0,205	0,741	-0,667	0,219
L	0,647	0,004*	0,884	<0,001*	-0,051	0,935	-0,051	0,935
M	0,858	<0,001*	0,933	<0,001*	0,718	0,172	0,289	0,637
N	0,784	<0,001*	0,754	<0,001*	0,289	0,637	0,410	0,493
LACL	0,744	<0,001*	0,706	0,001*	-0,410	0,493	0,667	0,219
TACL	0,444	0,065	0,801	<0,001*	-0,263	0,669	-0,205	0,741
LPCL	0,734	0,001*	0,776	<0,001*	-0,205	0,741	-0,051	0,935
TPCL	0,658	0,003*	0,725	0,001*	0,359	0,553	-0,359	0,553
FAR	0,212	0,399	0,245	0,327	-0,154	0,805	-0,763	0,133
TAR	0,141	0,576	-0,372	0,128	0,872	0,054	0,359	0,553

*: *significant at 0.05 level in bold characters*

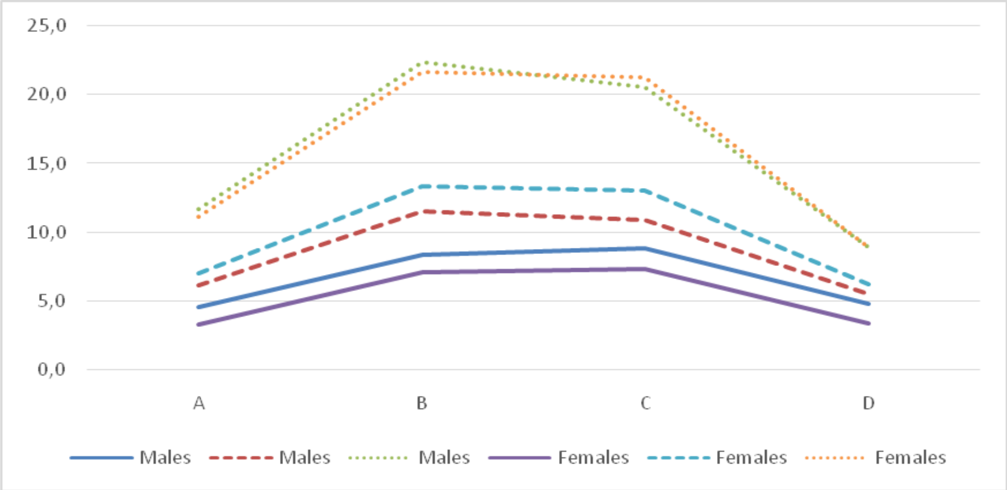

Figure 1. The means of A, B, C and D measurements according to gestational age in genders

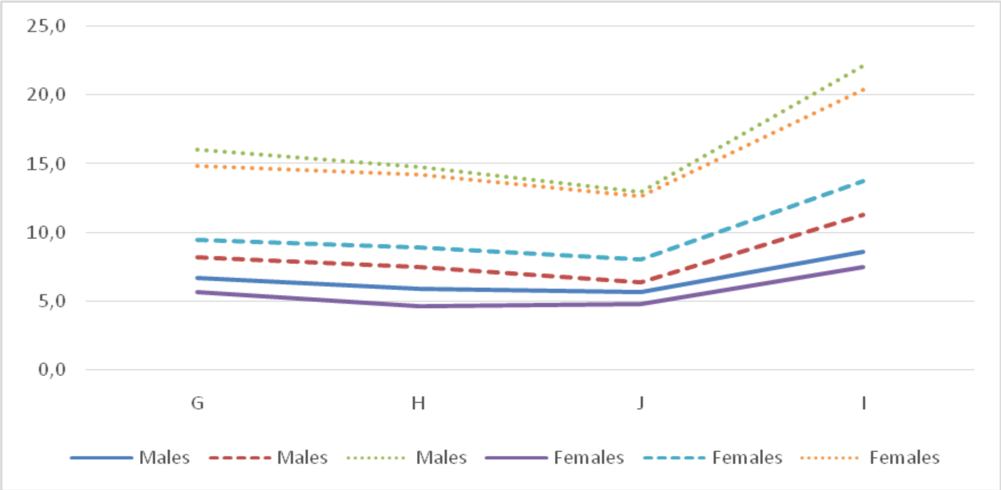

Figure 2. The means of G, H, J and I measurements according to gestational age in genders

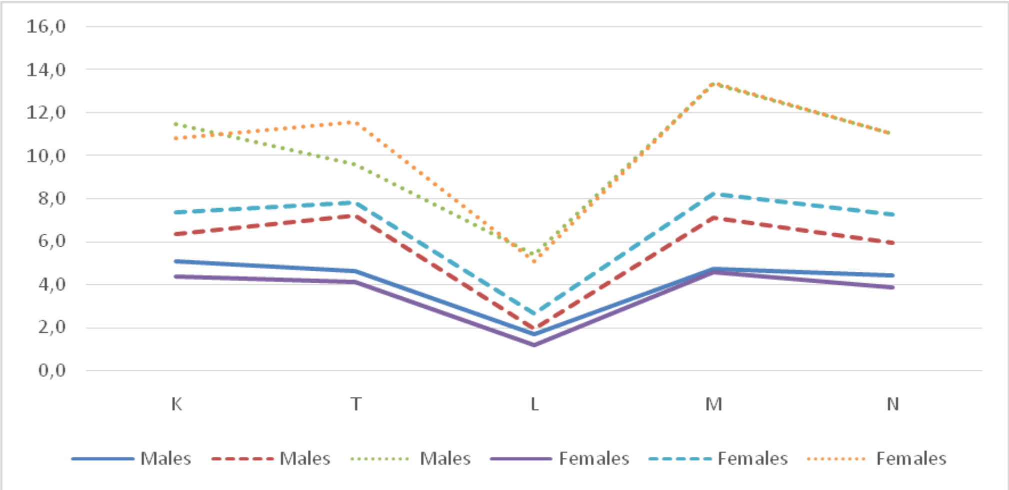

Figure 3. The means of K, T, L, M and N measurements according to gestational age in genders

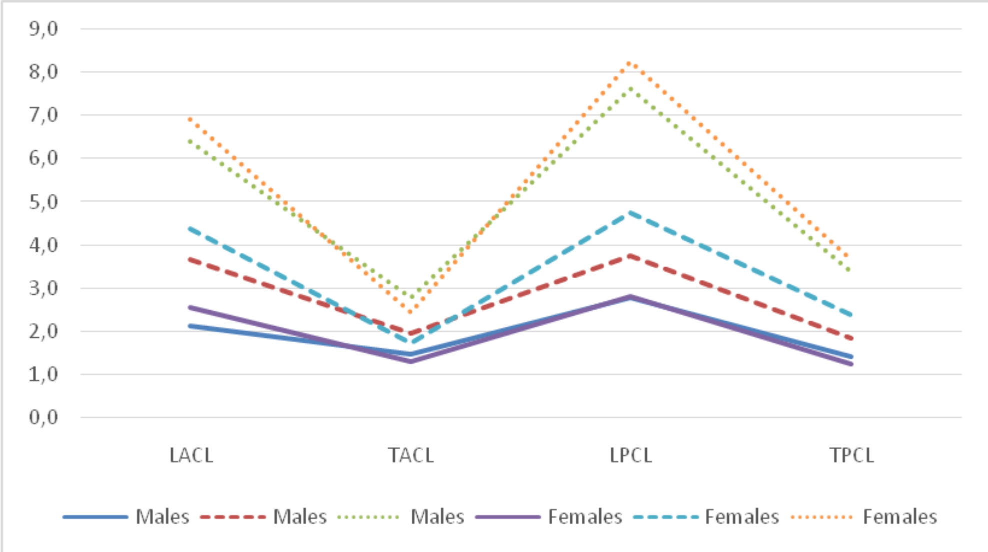

Figure 4. The means of LACL, TACL, LPCL and TPCL measurements according to gestational age in genders

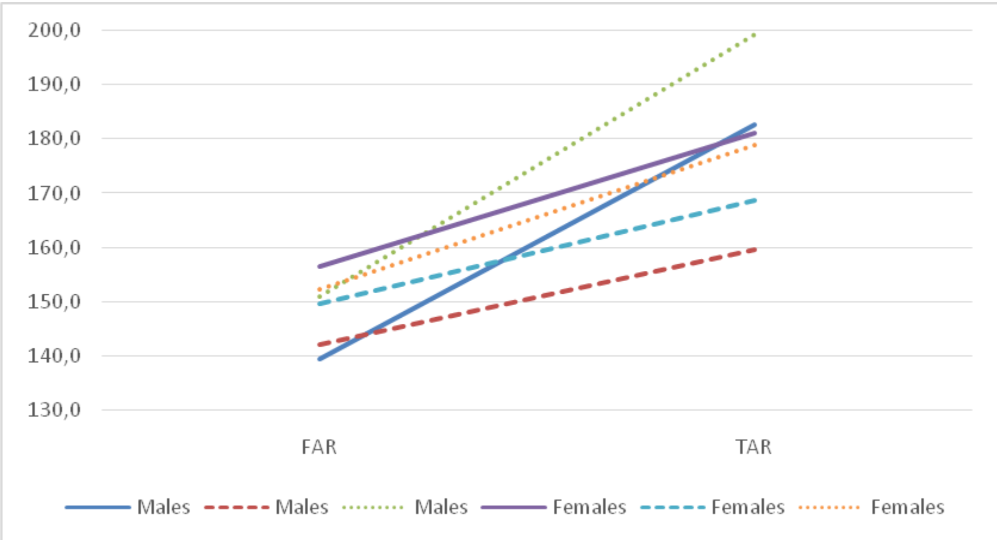

Figure 5. The means of FAR and TAR measurements according to gestational age in genders

4. DISCUSSION

Precise linear measurements of the fetus enable a full profile of the fetus and bring a new dimension to the measurement of its growth. In the current study, no significant gender and sides difference regarding knee joints and its component during the fetal life was found. Ziylan and Murshed (Ziylan-Mushid 2003:29) reported that the epicondylar widths were 14.92 mm in females, 14.78 mm in males in 2nd trimester, and 20.83 mm in females, 20.81 mm in males during 3rd trimester. These significant differences between males and females were in line with our findings related to the epicondylar width. Moreover, results of the study revealed that the medial condylar width and lateral condylar width of men were significantly greater than that of women.

Racial differences in the population should be taken into consideration; hence, we felt that using a heterogenous population was more appropriate rather than separating into different racial groups. This should provide a more universally applicable growth curve (O’Brien-Quenan 1981:834). We suggest that a comformable size chart for fetal parameters be created for the Turkish population, which has a wide range of study samples. Although CRL can be used to determine the gestational age of the fetus (Hesinger 1992:1692; Singer, et al. 1991:43), this standard was found to assess gestational age in the first trimester accurately (Hadlock, et al. 1982a:360; Deter, et al. 1987:490; Robinson 1975:105).

The difficulties faced while imaging the knee joint and its components, especially during 1st and 2nd trimesters have been reported by previous ultrasound studies including those with 3D ultrasound. In this study, the knee joint and its components between 11-37 weeks of gestation were measured and a significant relationship was determined between knee joint and its components and gestational age during this period ($p<0.001$). The data obtained in this study contains detailed information on the intrauterin development of the fetal extremities, especially knee joints and its components.

No significant gender differences related to knee joint and its components during the fetal life were observed in previous studies. Yet, in adults, a gender difference was found between lateral tibial condyle and medial tibial condyle (Mc Fadden-Shubel 2002:498). In most males the lateral tibial condyle is smaller than the medial tibial condyle. In our study no laterality differences were found in knee joint and its components between gender or sides ($p>0.05$). When the knee joint and its components among trimester groups were compared, a significant difference was found in medial plateau and lateral plateau of the tibial anterior posterior measurements among all groups.

In the present study, the length and width of the patella was observed to increase with gestational age and this increase was statistically significant ($P<0.05$; Table 2). The increases in the length and width also showed a linear relationship throughout the fetal period. In addition, positive correlations were found between the length and width of the patella and body weight-CRL ($p<0.05$). In terms of gender, the mean length of the patella was larger in females, which was not statistically significant.

It is important to know the thickness of the patella in adults and no studies have been conducted on this topic. However, to our knowledge, there are no studies on this structure and fetal period (Yoo, et al. 2007:626; Sulaiman-Nordin 2005:43). In addition, the thickness of the patella showed a significant correlation with the height and weight of patients (Sulaiman-Nordin 2005:43). In our study on fetal specimens, there were positive correlations between the thickness of the patella and body weight-CRL, and the thickness was observed to increase with gestational age (Table 2). This results demonstrate that the thickness of patella, body weight and CRL all increase at the same ratio before the lower extremities bear and load.

A gender difference was seen in femur aspect ratio and tibia aspect ratio ($p<0.05$) (Table 1,Table 2). Femur aspect ratio, tibia aspect ratio on the right; 144.62, 175.64, 150.89, 172.10, on the left 145.22, 186.87, 140.04, 187.52, male and female, respectively. There were significant differences between trimesters ($p<0.05$) (Table 2).

5. CONCLUSION

In this study, morphologic variations were more frequent on the right side in females. In terms of the average length of the right and left knees, there was no statistically significant difference between males and females ($p>0,05$). The measurements of the knees were determined to be able to be used as a parameter for the fetal body development since they correlated with CRL. In this study, the general morphologic features, variations and morphometric evaluations of the elements involved in the knee formation and knee structures of human fetuses were obtained. The materials used in this study taken from aborted fetus collection were considered morphologically normal. Nevertheless, both the factors affecting growing process of intrauterine period and the possible relation with the negative effects of the causes of abortion on growth should be taken into consideration. Since there are no studies directly related to the study on fetuses in the literature, this study was compared with similar neonatal period studies and limited number of cadaver studies. It is believed that this clinically important area can be analyzed morphologically better when similar studies are conducted on adult cadavers. We hope that the data obtained in this study will facilitate other studies on the diagnosis and treatment of such conditions carried out in obstetric, perinatology, forensic medicine and fetal pathology departments in addition to the anomalies, pathologies and variations of the knee joint and its components.

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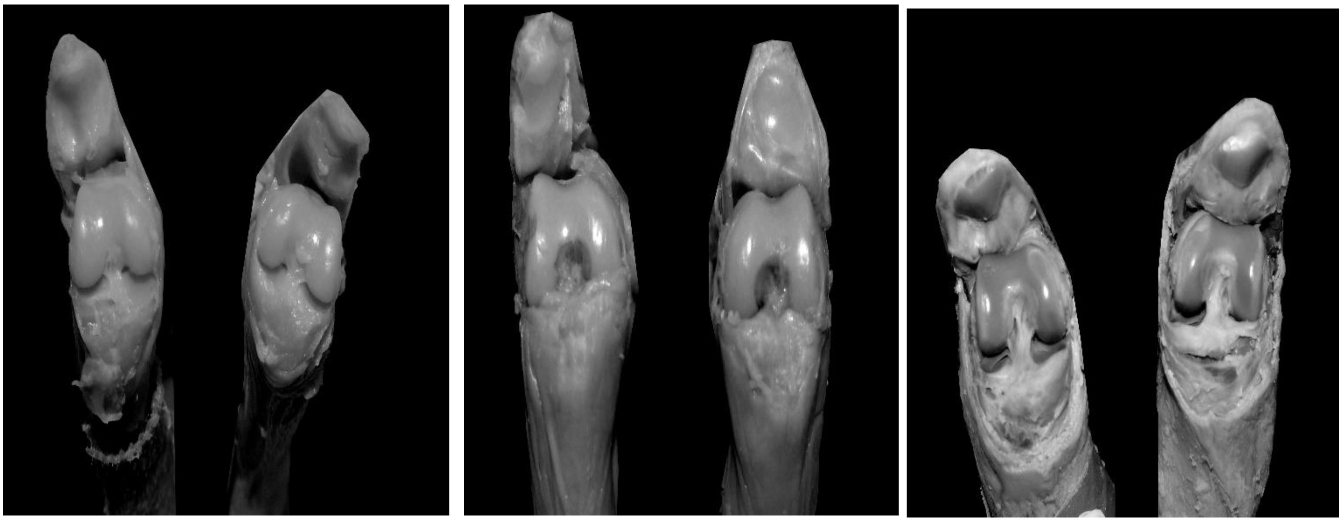

K1 K2 K3

Figure 6. Knees of 1st trimester (K1), 2nd trimester (K2) and 3rd trimester (K3) fetuses.

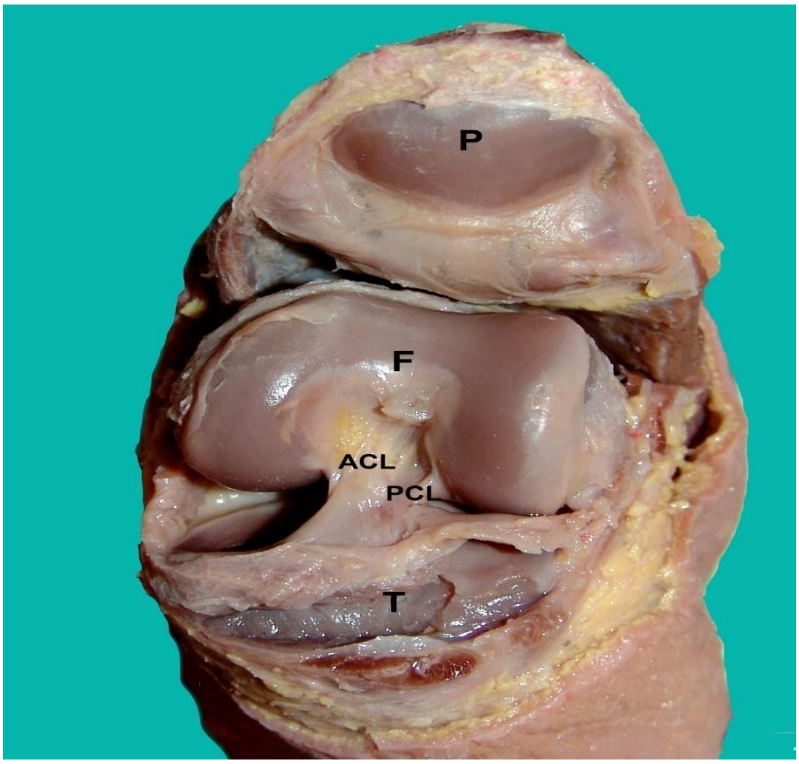

Figure 7. Anterior appearance of the knee from one of the examined fetuses at third trimester after dissection and during measurements. P: Patella, F: Femur, T: Tibia,

ACL: Anterior cruciate ligament, PCL: Posterior cruciate ligament