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EXPERIMENTAL / LABORATORY STUDIES

An Investigation of the Acetabulum, the Femoral Head and the Ligament of Femoral Head in Human Fetuses

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Abstract: We investigated the morphometric characteristics of the acetabulum, the ligament of the femoral head (LFH) and the femoral head, and the relationships among them in 30 spontaneously aborted human fetuses. The maximum length and width of the LFH, the transverse and vertical diameters of the femoral head and the acetabulum, the height of the femoral head and the depth of the acetabulum were measured and the existence of any relationship among them was assessed statistically. The acetabulum was circular in 58.4% of cases and oval in 41.6%. The diameter of the femoral head was less than that of the acetabulum in 91.7% of subjects. In one case the base of the acetabulum was devoid of cartilage tissue. When all of the parameters were compared according to gender and lateralization, only the length of the LFH in females on the left side was greater than that on the right side ($P < 0.05$). There was a high correlation between the diameters of the acetabulum and the femoral head as well as the acetabular depth and the height of the femoral head. The relation between gestational age and the measured data was significant ($P < 0.05$). The presented data may help to explain the effect of hip joint morphology during developmental stages on the process of some congenital hip joint diseases.

Key Words: Ligament of the femoral head, Acetabulum, Human fetus

Introduction

All structures of the human hip are visible at the 6^{th} week of intrauterine life (1). At the end of the 8^{th} week, the early cartilage model of the acetabulum and the femoral head appear and at the 11^{th} week (approximately at the end of the 1^{st} trimester) all of the components of the hip joint can be observed easily. Following birth, the acetabulum and the proximal part of the femur continue to grow (2-4). The acetabular fossa is at the inferomedial part of the acetabulum and contains fatty tissue and the ligament of the femoral head (LFH) (5). Throughout the early fetal period (13-20 weeks), the hip joint is completely closed and the LFH, which lies between the acetabular fossa and fovea for the ligament of the head, is located deeply. For this reason, the LFH cannot be visualized easily by simple imaging techniques (6).

Knowledge of embryology and the early development of the hip joint is necessary to understand correctly the developmental dysplasia and dislocation of the hip joint (DDH) (7). Several investigators have studied the development of the hip joint to explain the etiology of DDH (8-10). There are no reports in the literature on dislocated hips in fetuses earlier than the 3^{rd} trimester (10).

In this study, we investigated the morphometric characteristics of the acetabulum, the LFH and the femoral head, and the relationships among them at the 2^{nd} and 3^{rd} trimesters of human fetal life.

Materials and Methods

Thirty (15 female, 15 male) human fetuses were examined. These spontaneously aborted fetuses had no apparent pathologic features and were fixed with 10% formalin using immersion. The estimated fetal age according to crown rump length (CRL) (11) ranged between 20 and 33 weeks. The capsule of the hip joint was removed, and the acetabulum, the LFH and the femoral head were exposed in 60 hip joints of 30 fetuses. The maximum length and width of the LFH were measured and analyzed with the hip in abduction (Figure 1). The insertion of the LFH to the femoral head was cut. Afterwards, the transverse and vertical diameters of the femoral head were measured in full abduction of the hip (Figure 2a). Following removal of the femoral head, the transverse and vertical diameters of the acetabulum were also measured as illustrated (Figure 2b). The height of the femoral head was measured between the line where the cartilage of the hip joint began to appear and the highest point of the femoral head, as shown in Figure 2b. After this process, the acetabulum was filled completely with polyvinyl chloride (Sigma, 9002.86.2) to obtain a cast of it (Figure 3) and then the depth of the acetabulum was measured between the top and bottom of the cast. All measurements were performed using electronic digital calipers (150 x 0.01 mm) by the naked eye.

The data were compared according to gender by Student's t-test and to compare lateralization nonparametric Wilcoxon signed rank's test was used, as the distribution was not homogeneous, and the relationships between the measurements were evaluated with Pearson's correlation test (SPSS 6.0 Windows 98). The results are presented in Tables 1-3.

Results

Two different types of acetabular shape were observed: circular and oval. In all of the oval shaped acetabuli, the vertical diameters were 20% less than the transverse diameters. Circular acetabul were observed in 58.4% (16 female, 19 male) of the hip joints and oval ones in 41.6% (14 female, 11 male). All of the femoral heads were spherical. The diameter of the femoral head was less than that of the acetabulum in all but 5 (8.3%) cases. The height of the femoral head was greater than the depth of the acetabulum, except in 2 (3.3%) cases. In these 2 hip joints, the acetabulum was 3 mm deeper than the height of the femoral head. The height of the femoral head was 0-1 mm greater than the depth of the acetabulum in 7 (11.7%) cases, 1-4 mm greater in 46 (76.7%) cases, and more than 4 mm greater in 5 (8.3%) cases. In 1 case, there was only soft tissue instead of cartilage formation at the base of the acetabulum (Figure 4). The presence of the LFH was observed in all cases and it lay between the fovea of the femoral head and the acetabular fossa.

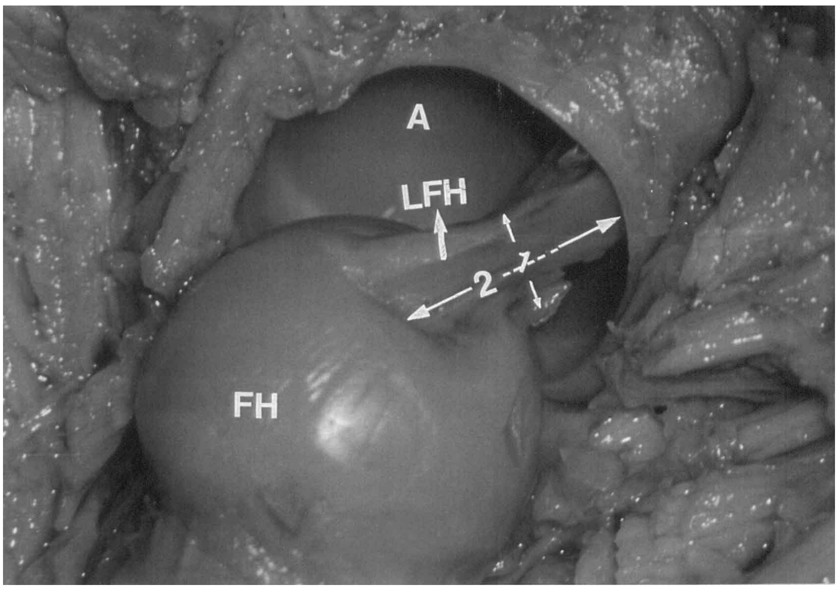

Figure 1. Acetabulum (A), ligament of the femoral head (LFH) and the femoral head (FH) were dissected in the hip joint at 20 weeks of gestation. The maximum width of the LFH (1) and the maximum length of the LFH (2) were measured (C10).

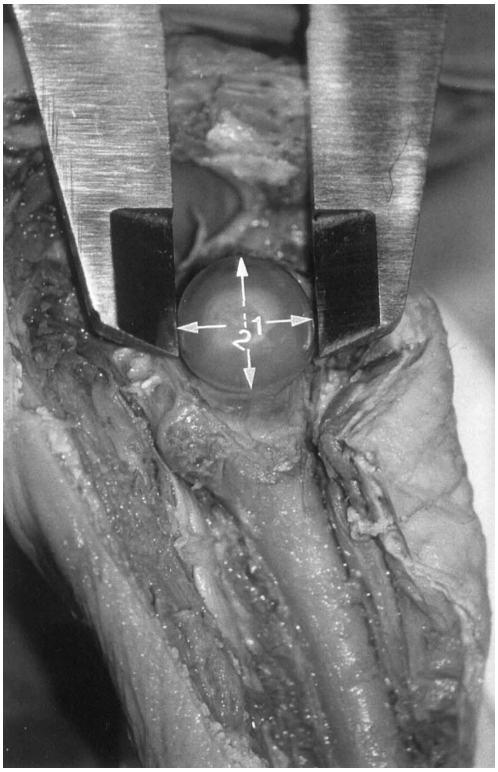

Figure 2a. The transverse (1) and vertical (2) diameters of the femoral head (3) were measured at 22 weeks of gestation.

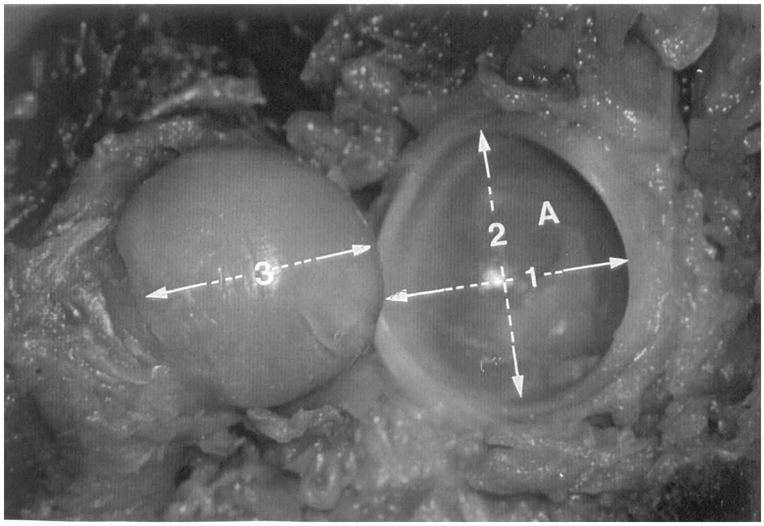

Figure 2b. The transverse (1) and vertical (2) diameters of the acetabulum and the height of the femoral head (3) were measured at 20 weeks of gestation (C10).

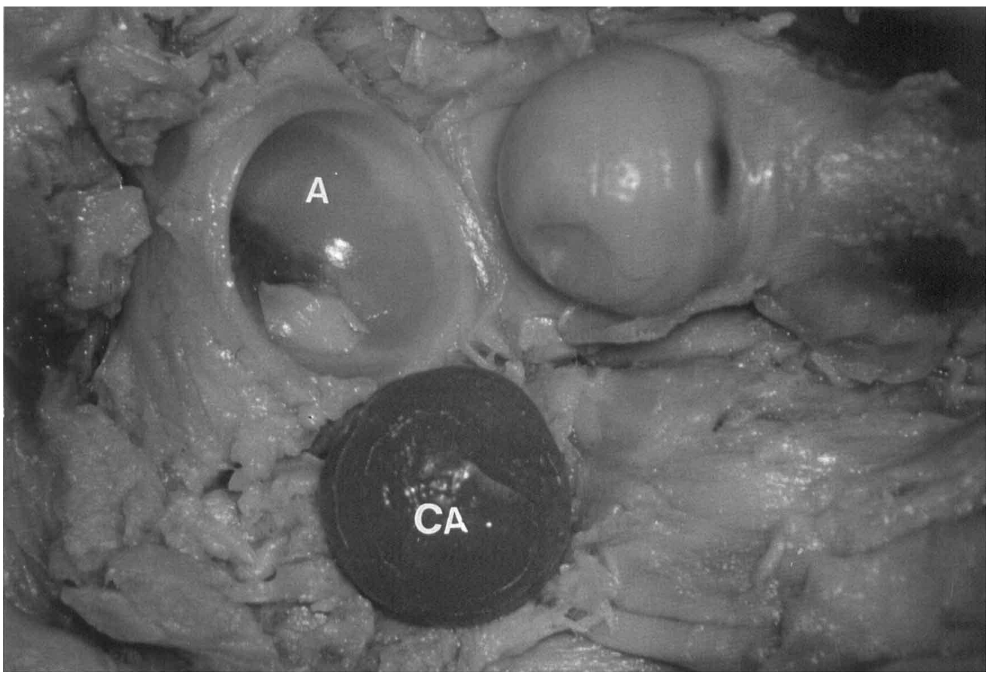

Figure 3. The acetabulum (A) was filled completely with polyvinyl chloride to obtain the cast of acetabulum (CA) at 26 weeks of gestation (FH: femoral head) (C6).

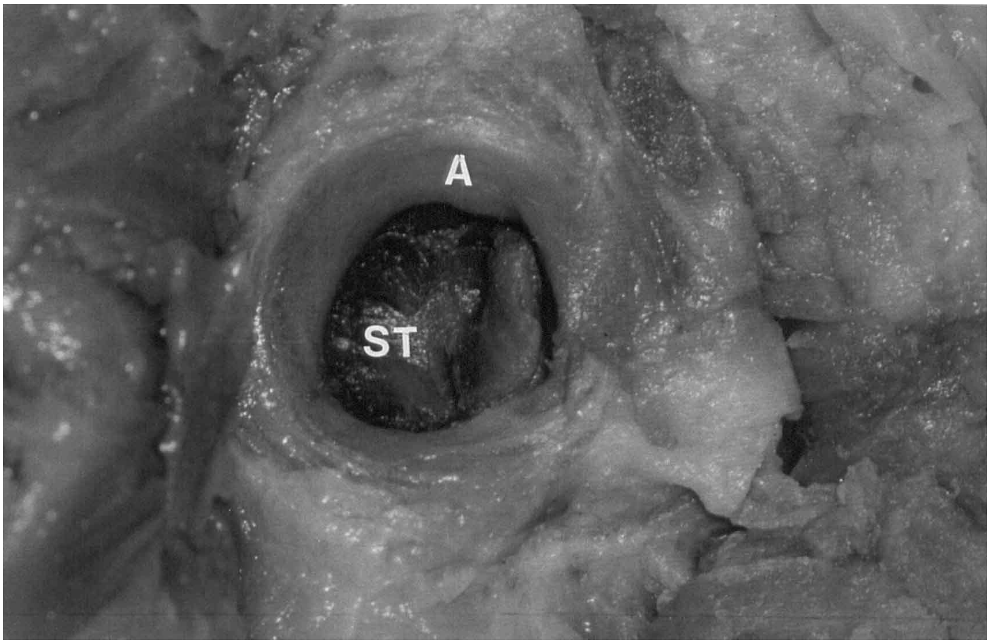

Figure 4. There was soft tissue (ST) instead of cartilage formation at the base of the acetabulum (A) at 27 weeks of gestation (C6).

Table 1. Comparison of the data (mm, average ± standard deviation) of the acetabulum, femoral head and LFH in fetuses according to gender and trimesters.

	2nd trimester			3rd trimester		
	Male (n = 9)	Female (n = 9)	P	Male (n = 6)	Female (n = 6)	P
DA_l	5.17 ± 0.41	5.42 ± 0.78	0.4	7.10 ± 0.62	8.02 ± 2.46	0.4
DA_r	5.14 ± 0.72	5.51 ± 1.12	0.4	6.87 ± 0.65	7.92 ± 2.60	0.4
TDA_l	8.69 ± 1.23	8.86 ± 1.21	0.8	12.67 ± 1.21	13.24 ± 1.36	0.5
TDA_r	8.67 ± 1.35	9.20 ± 1.20	0.4	12.69 ± 1.34	13.43 ± 0.69	0.3
VDA_l	7.62 ± 1.37	8.00 ± 1.75	0.6	10.11 ± 1.44	9.60 ± 0.98	0.5
VDA_r	7.18 ± 1.11	8.05 ± 1.49	0.2	9.72 ± 1.99	9.58 ± 1.11	0.9
$TDFH_l$	7.84 ± 1.08	8.31 ± 1.22	0.4	11.04 ± 1.19	11.69 ± 0.81	0.3
$TDFH_r$	7.78 ± 1.03	8.29 ± 1.23	0.4	11.34 ± 1.35	11.25 ± 0.75	0.9
$VDFH_l$	7.73 ± 1.18	8.21 ± 1.39	0.4	11.17 ± 1.17	11.70 ± 0.83	0.4
$VDFH_r$	7.76 ± 1.11	8.30 ± 1.23	0.3	11.24 ± 1.29	11.61 ± 0.67	0.6
HFH_l	6.74 ± 0.85	7.40 ± 1.11	0.2	9.01 ± 1.15	10.28 ± 0.58	**0.0***
HFH_r	6.62 ± 0.62	7.65 ± 1.30	0.5	8.84 ± 1.28	10.44 ± 0.70	**0.0***
$MWLFH_l$	1.85 ± 0.45	2.47 ± 0.43	**0.0****	3.97 ± 1.58	3.93 ± 1.20	1.0
$MWLFH_r$	2.07 ± 0.49	2.43 ± 0.44	0.1	3.70 ± 1.66	3.80 ± 1.22	0.9
$MLLFH_l$	4.88 ± 0.79	4.95 ± 0.50	0.8	5.97 ± 1.80	7.49 ± 1.13	0.1
$MLLFH_r$	4.74 ± 0.55	4.79 ± 0.38	0.8	5.84 ± 1.68	7.06 ± 1.08	0.2

DA: Depth of Acetabulum
TDA: Transverse Diameter of Acetabulum
VDA: Vertical Diameter of Acetabulum
HFH: Height of Femoral Head
VDFH: Vertical Diameter of Femoral Head
TDFH: Transverse Diameter of Femoral Head
MWLFH: Maximum Width of LFH
MLLFH: Maximum Length of LFH
** P < 0.01, * P < 0.05
l: left, r: right

Table 2. Comparison of the data (mm, average ± standard deviation) of the acetabulum, femoral head and LFH in fetuses according to side.

	Male		Female		Total	
	right (n = 15)	left (n = 15)	right (n = 15)	left (n = 15)	right (n = 30)	left (n = 30)
DA	5.83 ± 1.10	5.94 ± 1.09	6.47 ± 2.15	6.46 ± 2.06	6.15 ± 0.31	6.20 ± 1.64
TDA	10.28 ± 2.42	10.28 ± 2.34	10.89 ± 2.36	10.61 ± 2.54	10.58 ± 2.36	10.44 ± 2.40
VDA	8.19 ± 1.94	8.62 ± 1.84	8.66 ± 1.52	8.64 ± 1.66	8.42 ± 1.73	8.62 ± 1.72
TDFH	9.20 ± 2.12	9.12 ± 1.95	9.47 ± 1.81	9.66 ± 2.00	9.38 ± 1.96	9.33 ± 1.94
VDFH	9.15 ± 2.10	9.11 ± 2.08	9.61 ± 1.96	9.61 ± 2.11	9.38 ± 2.01	9.35 ± 2.07
HFH	7.51 ± 1.44	7.65 ± 1.48	8.77 ± 1.77	8.55 ± 1.72	8.13 ± 1.71	8.10 ± 1.64
MWLFH	2.72 ± 1.34	2.70 ± 1.47	3.05 ± 1.08	2.97 ± 1.06	2.87 ± 1.28	2.84 ± 1.19
MLLFH	5.18 ± 1.22	5.32 ± 1.35	5.70 ± 1.35	5.97 ± 1.50*	5.44 ± 1.29	5.64 ± 1.44*

DA: Depth of Acetabulum
TDA: Transverse Diameter of Acetabulum
VDA: Vertical Diameter of Acetabulum
HFH: Height of Femoral Head
VDFH: Vertical Diameter of Femoral Head
TDFH: Transverse Diameter of Femoral Head
MWLFH: Maximum Width of LFH
MLLFH: Maximum Length of LFH
* P < 0.05

Table 3. The correlation coefficient results of the data (mm, average ± standard derivation) of the acetabulum, femoral head and LFH in fetuses according to gestational age. The third column shows the 2nd and 3rd trimester cases together.

	2^{nd} trimester (n = 18)		3^{rd} trimester (n = 12)		2^{nd} and 3^{rd} trimester (n = 30)	
		r		r		r
DA_l	5.29 ± 0.62	0.41	7.56 ± 1.78	-0.29	6.20 ± 1.64	0.59**
DA_r	5.33 ± 0.93	0.59*	7.39 ± 1.89	-0.20	6.15 ± 1.71	0.58**
TDA_l	8.77 ± 1.19	0.36	12.96 ± 1.26	0.45	10.44 ± 2.40	0.85**
TDA_r	8.94 ± 1.27	0.60**	13.06 ± 1.09	-0.18	10.58 ± 2.37	0.84**
VDA_l	7.81 ± 1.53	0.33	9.85 ± 1.21	0.05	8.63 ± 1.72	0.61**
VDA_r	7.62 ± 1.35	0.46*	9.65 ± 1.54	-0.08	8.43 ± 1.73	0.61**
$TDFH_l$	8.07 ± 1.15	0.45	11.36 ± 1.03	0.35	9.39 ± 1.96	0.84**
$TDFH_r$	8.04 ± 1.13	0.42	11.29 ± 1.04	0.37	9.34 ± 1.95	0.83**
$VDFH_l$	7.97 ± 1.28	0.49*	11.43 ± 1.01	0.30	9.35 ± 2.08	0.85**
$VDFH_r$	8.03 ± 1.17	0.42	11.43 ± 1.00	0.26	9.39 ± 2.01	0.84**
HFH_l	7.07 ± 1.02	0.48*	9.64 ± 1.09	0.39	8.10 ± 1.64	0.82**
HFH_r	7.14 ± 1.12	0.55*	9.64 ± 1.29	0.37	8.14 ± 1.71	0.80**
$MWLFH_l$	2.16 ± 0.54	0.31	3.95 ± 1.39	0.29	2.88 ± 1.28	0.66**
$MWLFH_r$	2.25 ± 0.49	0.24	3.75 ± 1.34	0.42	2.85 ± 1.20	0.68**
$MLLFH_l$	4.92 ± 0.64	0.52*	6.73 ± 1.64	0.30	5.64 ± 1.44	0.67**
$MLLFH_r$	4.77 ± 0.46	0.30	6.45 ± 1.49	0.42	5.44 ± 1.29	0.67**

r = correlation coefficient,
DA: Depth of Acetabulum
TDA: Transverse Diameter of Acetabulum
VDA: Vertical Diameter of Acetabulum
HFH: Height of Femoral Head
** P < 0.01, * P < 0.05,
VDFH: Vertical Diameter of Femoral Head
TDFH: Transverse Diameter of Femoral Head
MWLFH: Maximum Width of LFH
MLLFH: Maximum Length of LFH
l: left, r: right

When the results were compared according to gender and trimester, on the left side, the mean maximal length of the LFH in females was greater than that in males in the 2^{nd} trimester ($P < 0.01$). The mean height of the femoral head in females was greater than that in males in the 3^{rd} trimester on both sides, and this difference was statistically significant ($P < 0.05$) (Table 1). All of the parameters were compared according to lateralization (left and right side), and on the left side only the length of the LFH in females was greater than the right side, and this difference was statistically significant ($P < 0.05$) (Table 2).

There was a highly positive correlation between the transverse diameters of the acetabulum and the femoral head (at the right side r: 0.92; at the left side r: 0.94), the vertical diameters of the acetabulum and the femoral head (at the right side r: 0.76; at the left side r: 0.86), and the depth of the acetabulum and height of the femoral head (at the right side r: 0.71; at the left side r: 0.67). There were statistically significant correlations between gestational age and the measured parameters, but the significance degree varied. When the correlations between the parameters and gestational age were analyzed according to trimesters, the acetabular depth showed a slight increase when the 2^{nd} and 3^{rd} trimesters were compared (Table 3). There was a statistically significant correlation ($r = 0.72$) between the transverse diameter of the acetabulum and the maximum length of the LFH in oval acetabuli, but there was a moderately significant correlation ($r = 0.54$) in spherical acetabuli.

Discussion

Studies by clinicians using the naked eye were not sufficient to diagnose developmental dysplasia or dislocation of the hip (12) and it was stated that further morphometric studies were needed for clinical applications (8,10). According to the literature, 80% of cases of developmental dislocation of the hip were in females (3), the pathology was on the left side in 60% of cases, on the right side in 20%, and bilateral in the remaining 20% (2). It was reported that the 12^{th}, 18^{th} and final 4 weeks of the gestation period had a risk for DDH and 3 different theories (namely hormonal, mechanic and hereditary) were suggested (2,3,13-15).

Walker and Goldsmith (9) measured the diameter and depth of the acetabulum, the diameter of the femoral head and the maximum length and width of the LFH in human fetuses. They could not find any differences between males and females and the left or right sides of the fetuses. However, in the present study there was a statistically significant difference ($P < 0.05$) between the sides regarding the length of the LFH in female fetuses.

Walker and Goldsmith (9) reported that during the period studied by them, the development of acetabular depth was the slowest, increasing less than 4-fold between 12 and 42 weeks. Wojciuk and Zajac (16) and Juszcza (17) reported that acetabular depth decreases during the fetal period and reaches the smallest size at birth. In the present study, the increase in the depth of the acetabulum with age (20-33 weeks) was determined. However, negative correlation was found between gestational age and the increase in depth in the 3^{rd} trimester. There was a slight increase in acetabular depth between the values of the 2^{nd} and 3^{rd} trimester. Our results indicated that the increase in acetabular depth in the 3^{rd} trimester was not proportional to gestational age, in accordance with previous studies.

Walker and Goldsmith (9) showed that there was a strong relationship between the diameter of the femoral head and the diameter of the acetabulum ($r = 0.86$). They found that the diameter of the femoral head was greater than that of the acetabulum in most of the fetal hips. Weinstein (3) emphasized that in the normal hip joint the femoral head was located deep in the acetabulum at birth. In our work, there was a strong correlation between the diameter of the femoral head and that of the acetabulum ($r = 0.67$-0.94). Furthermore, the diameter of the femoral head was less than that of the acetabulum in 55 (91.7%) of 60 hip joints and the diameter of the femoral head was greater than that of the acetabulum in 5 (8.3%) of 60 hip joints. Regarding the diameter of the femoral head and the acetabulum, our results were consistent with those of Weinstein (3).

Walker (12) emphasized that, with a 5-fold increase, the most rapid growth was in the length of the LFH from the 12^{th} week to term. Our results did not support those of Walker (12).

In previous studies it was emphasized that all acetabuli examined were circular and the pressure of the femoral head might affect the formation of the acetabular shape (2,3). We observed that the acetabulum was circular in 35 (58.4%) cases, and oval in 25 (41.6%) cases. In the present study, a correlation was found between the transverse diameter of the acetabulum and the maximum length of the LFH in both the oval and circular acetabuli, but the correlation degree was higher in oval acetabuli (r = 0.72) than in circular ones (r = 0.54).

The success of treatment in developmental dysplasia or dislocation of the hip depends on an early diagnosis. In previous studies it has been shown that the soft tissues play an important role in hip joint stability during the fetal period. It would not be appropriate to make a generalization without sufficient knowledge about the development and morphology of the hip joint and the relationship between them. Our results suggesting that there is an association between increased LFH length and oval acetabuli are interesting given the known prevalence of DDH in females and in the left hip.

In conclusion, the data provided in our study about the morphological appearance, morphometric values and relationship between the structures of the hip joint may help physicians to make an appropriate decision during the clinical diagnosis of DDH using imaging techniques such as ultrasonography and magnetic resonance imaging. In addition, the presented data may be useful to explain the effect of the development of hip joint morphology on the process of some congenital hip joint diseases and to develop new treatment approaches related to the developmental anatomy of the region. The present study might stimulate future research such as the use of high resolution pre-natal ultrasound to measure acetabular parameters in utero and to examine whether ultrasound measurements are correlated with clinical instability or dysplasia.

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