RESEARCH ARTICLE

Sonographic Hip Angles in Relation to Gestational Age of Neonates. A Prospective, Cohort in the Population of Northern Greece

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Abstract

Objectives: Developmental dysplasia of the hip (DDH) is a condition with variation among ethnicities and regions. We aimed to investigate the effect of a gestational week of birth on the sonographic acetabular hip angles of newborns.

Methods: We prospectively scanned the hips of neonates born in a single, tertiary hospital during their first week of life, using the Graf sonographic method. Demographics, obstetric history of the mother, birth weight, parity, presentation, family history of developmental dysplasia of the hip (DDH), gender, mode of delivery, single/multiple birth, and gestational age were recorded. Acetabular α and β angles were measured, and hip type was determined according to Graf's classification. Patients were divided according to the gestational age of birth (<37 weeks, 37-38, 38-39, 39-40, >40 weeks).

Results: From May- October 2020, 342 babies (684 hips) were examined (52.9% males / 47.1% females). 76.7% were Caucasian-Greek, and 88.3% were term babies. There was a significant difference between the α-angles of the right and left hip in both genders. More females had Type II hips than males. Subgroup analysis did not reveal a significant difference in hip angles of term babies. There was no correlation between birth weight or gestational age and hip angles. Female gender and the existence of maternal thyroidopathy were positively correlated with Type II hips.

Conclusion: Gestational birth age in term infants is unimportant regarding acetabular hip angles. Female gender and maternal thyroidopathy appeared to be related to hip type. Further investigation may be warranted to elucidate the effect of maternal thyroidopathy and hip development.

Level of evidence: II

Keywords: Hip angle, Hip dysplasia, Gestational age, Greece, Sonographic

Introduction

Developmental dysplasia of the hip (DDH) is characterized by changes in size, shape, orientation, and organization of the femoral head, the acetabulum, or both. It encompasses a wide range of abnormalities of the pediatric hip, ranging from physiologic immaturity to frank dislocation. It is important to understand that it is a condition that can develop postnatally. Since the introduction of ultrasound

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screening, which has high sensitivity in the first months of life, we have detected subtle variations of the infantile hip that could not be recognized by clinical examination only.[1–3] Barlow noted that most infantile unstable hips would become normal by two months, which probably reflects the sonographic DDH hips that will resolve spontaneously.[4] The optimal timing for sonographic screening of the hip is 4-6 weeks after birth.[5–7] In premature babies, screening for DDH before 38 weeks may often lead to subsequent ultrasonography and overtreatment, but gestational age is not considered in term babies. [8–13]

DDH is a condition with significant variability among ethnicities and regions.[14] Studies have shown that infants of Caucasian ethnicity have a sonographic incidence of DDH ranging from 7.6 - 847/1000births at birth, which decreases to 12.8-14.8 by six weeks.[15,16] In Turkey, the estimated incidence at six weeks is births 47.1000[17]; in Greece (Crete), it is reported and 10.6/1000 births [18] births at two weeks.

It has been suggested that the last five weeks of gestation and the first weeks of life are important regarding hip development.[19–24] The impact of gestational age on hip maturation in preterm and term infants is reported in a few studies in southeast Europe.[25–27]

Given the variability of DDH among ethnicities, countries, and even regions among nations, we aimed to investigate the impact of gestational age on sonographic hip angles in our region. We hypothesized that we would get more mature sonographic hip angles as gestational age increased.

Materials and Methods

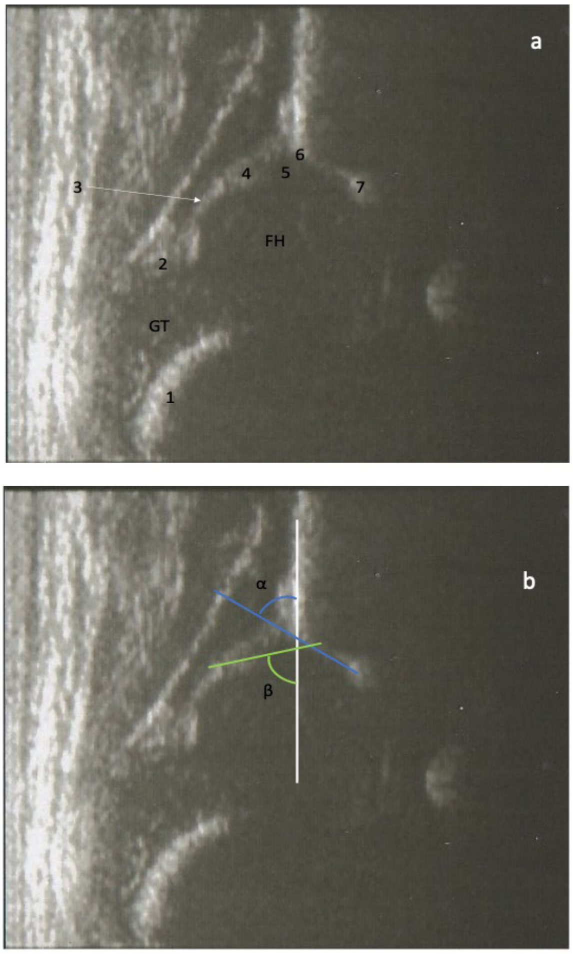
The current study was performed according to the STROBE Statement for observational studies.

We prospectively scanned the hips of consecutive neonates born in a single tertiary center during the first week of life and calculated the sonographic α and β angles according to Graf's method. Inclusion criteria consisted of all healthy infants born in our hospital. Infants screened later than the first week of life, and those of unknown gestational age were excluded from the final analysis. Premature infants hospitalized in the Neonatal Intensive Care Unit were not available for screening.

Each examination was performed by two Fellowship trained Paediatric Orthopaedic Surgeons, and images were validated by a senior Paediatric Orthopaedic Surgeon with more than ten years of experience, using the General Electric LOGIQ 200 PRO Series ultrasound machine with a 9 MHz linear probe. We used the static method described by Graf 28 and the Baby SonoFix cradle, where the baby is placed in the lateral decubitus position with the hip flexed 35° and internally rotated 10o and the ultrasound probe fixed in a vertical position.[29] For the images to be valid, we included all the anatomic landmarks of the hip as described by Graf, while measurements and classification were estimated following his method [Figure 1, Table 1].[28]

Demographic characteristics, obstetric history of the mother (maternal thyroidopathy), birth weight, gender, ethnicity, gestational age, parity, presentation, mode of delivery, single/multiple births, positive family history for DDH (1st degree relatives), and the results of the clinical evaluation were also recorded. Patients were divided into two groups, preterm neonates (<37 weeks of gestation) and term neonates (≥37 weeks), as defined by the World Health Organization.30 For subgroup analysis, we further divided them into <37 weeks, 37-38, 38-39, 39-40, and >40 weeks gestational age. Gestational age was calculated using information from the last menstrual period and ultrasound measurements of the embryo from the first trimester in cases where the previous was available.

The acetabular bony roof α-angle and cartilaginous roof β-angle were measured, and the distribution of



a. Anatomic landmarks of hip ultrasound -GT:Great Trochnter; FH: Femoral Head; 1: Chondrosseous border; 2:Synovial Fold; 3: Joint Capsule; 4:Labrum; 5: Hyaline Cartilage; 6: Bone Rim; 7: Lower limb of Illiac bone
b. Hip angle measurement- White line is the standard line ; Blue line connects lower limb of the illiac bone with the bony rim; Green line is formed from the bisector of the labrum and the point where the concavity falls to convexity of the acetabular roof

Figure 1. Hip ultrasound scans performed according to Graf's Method.

Table 1. Graf's Classification system of developmental dysplasia of the hip based on ultrasound measurements

Type	*α angle*	*β angle*	*Age*	*Morphology*
Ia	>60	<55	any	Angular-Normal
Ib	>60	>55	any	Angular-Normal
IIa	50-59		<3 months	Acetabulum Rounded-Sufficient/ Immature
IIb	50-59		>3 months	Acetabulum Rounded-Insufficient/Immature
IIc	43-49	<77	any	Acetabular Deficiency
D	43-49	>77	any	Acetabular Deficiency- Decentering
IIIa/IIIb*	<43		any	Dislocated-Flat-Poor Acetabulum/Labrum displaced cranially
IV	Unmeasurable	Unmeasurable	any	Dislocated-Flat-Poor Acetabulum/Labrum displaced caudally and medial

* Difference in histological changes

hip type was defined for each age group according to Graf's classification 28. In our analysis, a transverse presentation was considered cephalic since it has not been proven to increase the probability of hip dysplasia. [31,32] Regarding ethnicity, we formed three groups (Caucasian-Greek, Caucasian-Balkan, and Others). The mean roof angles and hip type were calculated for each group, and group comparisons according to gender and side were performed. The relationship between hip type and birth weight, gestational age, gender, maternal thyroidopathy, parity, presentation, mode of delivery, single/multiple births, and family history was also examined. Mothers with hypothyroidism during pregnancy or those treated for Hashimoto's disease were considered to have thyroidopathy.

Statistical Analysis

Statistical analysis was performed using the GNU PSPP 1.4.1-2software. Demographic data are presented as means with standard deviation (SD) and percentages. P-values of Pearson's chi-square test was calculated, and when the expected cell count was less than 5, Fisher's exact test was used for group comparisons of categorical variables. For continuous variables, independent and paired samples t-tests were used, and one-way analysis of variance (ANOVA) for multiple group comparisons. When adjusting for confounding factors, logistic regression was used to investigate the effect of gestational age on the hip type. A *P-value<0.05* was considered statistically significant, and the confidence interval was 95%. Statistical analysis was performed independently for each hip side (right hip, left hip).

Results

From May to October 2020, the hips of 354 neonates were screened. As 12 neonates were excluded, 342 patients were included in our study for final analysis [Figure 2]. Most patients were of Caucasian-Greek ethnicity (76.7%). The male-to-female ratio was almost equal, and 88.3% were term babies. Detailed

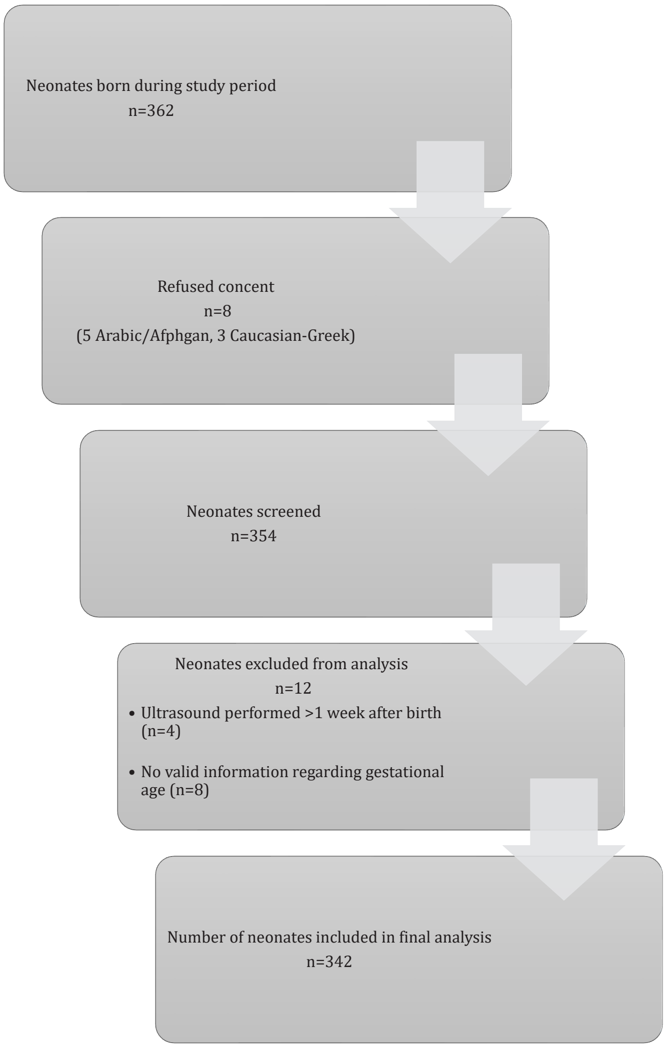


Figure 2. Flow Diagram of included patients.

Table 2. Population Characteristics Table

Gender	n(%)	(Pre)maturity	n(%)
Male	181(52.9)	<37 weeks (premature)	40(11.7)
Female	161(47.1)	>37 weeks (term)	302(88.3)
Ethnicity	n(%)	Graf Type R /L side	n(%)
Caucasian-Greek	262(76.7)	I	260(76)/276(80.7)
Caucasian-Balkan	47(13.7)	II	81(23.7)/66(19.3)
Arabic/Afghan	19(5.5)	III	1(0.3)/0(0)
Roma	11(3.2)	Birth Weight	Mean(SD)
African	3(0.9)	Overall	3189.7(537.9)
Presentation	n(%)	Male	3295,6(543,4)
Cephalic	313(91.3)	Female	3071,9(509)
Breech	17(5)	Gestational Age (days)	Mean(SD)
Transverse	3(0.9)		272(10.7)
Single/Multiple Birth	n(%)	Hip angle	Mean(SD)
Single	326(95.3)	α-angle	63.4(5.8)
Twin	16(4.7)	β-angle	71.17(6.6)
Parity	n(%)	Family History of hip dysplasia (1st degree)	n(%)
primiparity	113(33.1)	No	325(95.3)
Sequential	229(66.9)	Yes	16(4.7)

sample characteristics are presented in [Table 2]. The distribution of hip type according to gestational age is illustrated in [Figure 3].

Mean (SD) α and β angles were 63 (5.8) and 71.4 (6.7) for the right hip and 63.8 (5.7) and 70.9 (6.5) for the left hip, respectively. We found a statistically

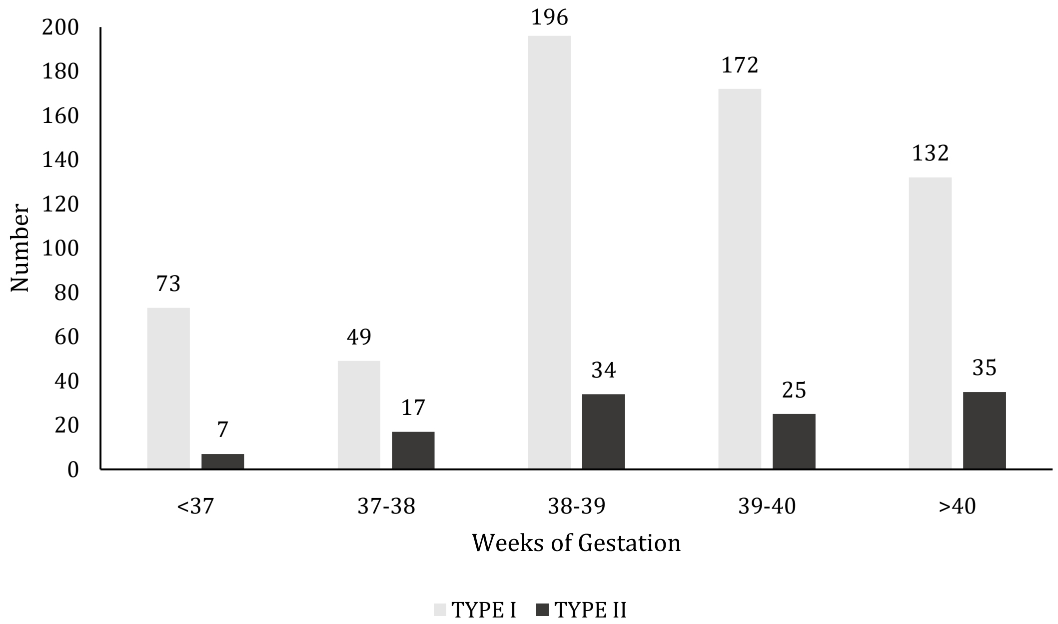


Figure 3. Hip Type distribution according to Gestational Age.

Table 3. Withing group comparisons of hip angles

	Mean(SD)	Paired t-test
α-angle (R)	62.9(5.8)	t= -3.79
α-angle (L)	63.8(5.7)	*P=0.0001**
β-angle (R)	71.45(6.7)	t= 1.70
β-angle (L)	70.9(6.5)	p=0.09
Females		
α-angle (R)	62.4(6.1)	t=-2.11
α-angle (L)	63.1(6.1)	*P=0.036**
β-angle (R)	72.1(6.5)	t= 0.67
β-angle (L)	71.8(6.3)	p=0.5
Males		
α-angle (R)	63.4(5.5)	t=-3.24
α-angle (L)	64.4(5.3)	*P=0.001**
β-angle (R)	70.8(6.8)	t=1.75
β-angle (L)	70(6.6)	*P=0.08*

*p: *P-value <0.05* statistically significant
SD: standard deviation; R: right; L: left

significant difference between the α-angle of the right and the left hip in both genders [Table 3]. Still, there was no difference in the mean hip angles in the subgroup analysis by gestational age [Table 4].

More females had Type II hips compared to males, while this difference was found statistically significant for neonates born <37 weeks, 38-39, and 39-40 weeks [Figure 4; Table 5].

No correlation was found between weight and acetabular α angle. There was no significant difference regarding hip type and weight, parity, presentation,

Table 4. Mean hip angles by gestational age

Gestational age (w)	α-angle Mean (SD)	β- angle Mean (SD)	Hip Type (I/II)
<37	63.4(5.43)	69.1(6.2)	73/7
37-38	63.6(6)	70.2(6)	49/17
38-39	63.8(5.8)	71.5(6)	161/34
39-40	62.7(5.5)	71.9(7.1)	131/47
>40	63.5(6.1)	72.3(6.9)	122/42
F-value	0.96	3.62	x^2=14.5
P-value	0.42	0.06	0.006*

* *P-value<0.05* is statistically significant
w:weeks; SD: standard deviation
x^2= 358.1 *P-value*=0.0001* for premature (<37w) vs term (>37w) and hip type
x^2=4.27 *P-value*=0.23 between term neonates and hip type

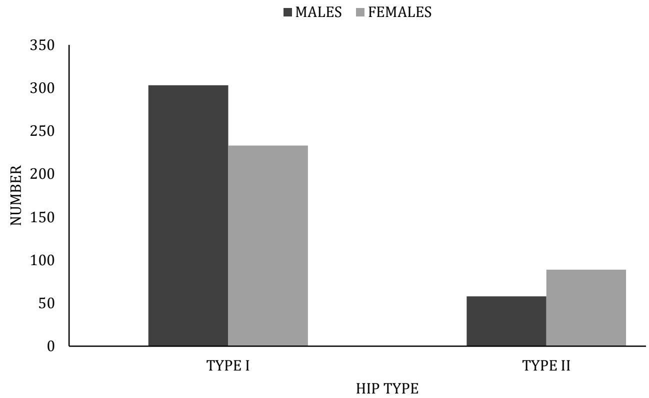


Figure 4. Distribution of Hip Type according to Gender.

Table 5. Comparisons of hip types by gender according to gestational age

	MALES	FEMALES	*P-value*
<37 weeks			
Type I	45	28	x^2=5.86
Type II	1	6	0.038*
37-38 weeks			
Type I	24	25	x^2=0.31
Type II	7	10	0.57
38-39weeks			
Type I	100	61	x^2= 4.88
Type II	14	20	0.029*
Type III	1	0	
39-40 weeks			
Type I	71	60	x^2= 4.5
Type II	17	30	0.035*
>40 weeks			
Type I	65	57	x^2=0.81
Type II	19	23	0.36
Overall			
Type I	303	233	x^2=14.39
Type II	58	89	0.001*
Right Hip			
Type I	144	116	x^2=3.86
Type II	36	45	0.12
Type III	1	0	
Left Hip			
Type I	159	117	x^2=12.6
Type II	22	44	0.0001*

**P-value*<0.05 statistically significant result

Table 6. Univariable and Multivariable comparisons of Hip type for the right side

Variables	Univariable Model			Multivariable Model		
	OR	95%CI	P-value	OR	95%CI	*P-value*
Gender	1.5	0.94, 2.5	0.086			
Parity	1.12	0.65, 1.9	0.664			
Presentation	1	0.33, 3.3	0.92			
Single/Twin Birth	0.44	0.09, 2	0.29			
Ethnicity						
Balkan/Greek	1.25	0.55, 2.8	0.58			
Other/Greek	1.09	0.39, 3	0.86			
Maternal Thyroidopathy	1.88	0.99, 3.84	0.09	2.7	1.2, 6.25	0.014*
Mode of Delivery	0.81	0.49, 1.33	0.41			
Prematurity	6.6	1.5, 33.3	0.01*	12.5	1.4, 100	0.022*
Birth Weight	1	1,1	0.27			
Family History of DDH	4	1.4, 11	0.009*	3.4	1.1, 10	0.027*

**P-value*<0.05 is statistically significant
OR: odds ratio; CI: confidence interval; DDH: developmental dysplasia of the hip

single/multiple births, and mode of delivery. Maternal thyroidopathy, prematurity, and positive family history of DDH were significant factors affecting hip type for the right hip and gender and maternal thyroidopathy for the left hip [Tables 6; 7].

Females [OR 3.1, 95%CI (1.6, 5.8)] and babies whose mothers had thyroidopathy [OR 2.5, 95%CI (1, 5.8)] were more prone to have type II left hip. The probability of having a type II right hip increased if there was maternal thyroidopathy [OR 2.7, 95%CI (1.2, 6.25)] and a family history of DDH [OR 3.4, 95%CI (1.1, 10)] [Table 7].

Table 7.

Variables	Univariable Model			Multivariable Model		
	OR	95%CI	P-value	OR	95%CI	*P-value*
Gender	2.7	1.5, 4.7	0.001*	3.1	1.6, 5.8	0.0001*
Parity	1.53	0.88, 2.66	0.132			
Presentation	1.4	0.44, 4,5	0.54			
Single/Twin Birth	3.74	0.48, 28.8	0.20			
Ethnicity						
Balkan/Greek	2.72	0.8, 9.24	0.10			
Other/Greek	1.75	0.42, 7.33	0.44			
Maternal Thyroidopathy	2.2	1, 4.7	0.035*	2.5	1, 5.8	0.035*
Mode of Delivery	1.03	0.6, 1.76	0.92			
Prematurity	8	0.66, 4.7	0.252			
Birth Weight	1	1,1	0.61			
Family History of DDH	2	0.6, 5.8	0.22			

**P-value*<0.05 is statistically significant
OR: odds ratio; CI: confidence interval; DDH: developmental dysplasia of the hip

Discussion

The human hip joint during the embryonic and early fetal period (up to 20 weeks) is characterized by a well-covered femoral head [21,23]. Intrauterine changes during the third trimester, described by anatomic studies, suggest a pause in the acetabular development in relation to the femoral head. This trend is reversed after birth, where there is a rapid increase in acetabular depth in the first months of life. [23,33-36] Stiegler et al. [37] examined pre and post-natally the hips of 40 infants using ultrasound and showed that fetal hips were mature at 34 weeks. Langer and Kaufmann 38 and Simic et al. [27], with a study population mainly of premature neonates, found that immature hips were more frequently observed in premature and underweight babies than in term babies. A weak association between gestational age and DDH was also found in a population-based study of preterm infants in Pomerania.39 In the sonographic study of Uludag et al. [26] that included 996 term infants with no known predisposing factors, the authors concluded that the acetabular maturation plateaued at 37 weeks of gestational age.

In our study, which consisted mainly of term neonates, there was no significant difference in the mean acetabular bony roof angle or hip type among term babies. In contrast, a significant difference was found between premature and term neonates according to hip type. There were proportionally more type II hips in the 37-38 weeks group compared to other groups with no significant difference.

These findings suggest that gestational age in term babies is not an important determinant when deciding the timing of ultrasound screening. Moreover, extrauterine acetabular development is much more significant than intrauterine in term babies.

Regarding predisposing factors, positive family history of DDH, gender, and maternal thyroidopathy was associated with type II hips. Maternal thyroidopathy significantly affected the type of hip, evident in both the right and left sides. In the literature, in only one study, maternal hyperthyroidism during the first trimester of gestation was found to be associated with DDH.[40] In a prospective cohort study by Su et al., isolated hypothyroxinemia was associated with fetal distress, small for gestational age, and musculoskeletal malformation.[41] Nevertheless, there is no consensus regarding the effects of isolated hypothyroxinemia on pregnancy. [42] Even though our sample was small, the indication of an association between maternal thyroid function during pregnancy and hip development denotes the need for further investigation

Limitations & Strengths

Our study was prematurely discontinued due to the COVID-19 pandemic outbreak, and our sample size was smaller than initially designed. Furthermore, for safety reasons, premature newborns hospitalized in the NICU were not available for screening. Consequently, we did not have neonates with severe types of hip dysplasia (IIc, IId, III, and IV), and data on premature babies are somewhat limited.

Our study is of prospective design, and to our knowledge, this is the first study coming from our region that addresses the relationship between gestational age and sonographic hip angles at birth and the first one to demonstrate that maternal thyroidopathy other than a family history of DDH or gender could be a factor related to DDH.

Our study found that gestational age in term babies is not an important factor affecting acetabular hip angles. Female gender was correlated with a higher incidence of left-sided hip immaturity, and maternal thyroidopathy was related to more immature hip types on both sides. Further investigation may be warranted to provide evidence regarding the effect of maternal thyroidopathy on DDH.

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