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Developmental Hip Dysplasia and Early Diagnosis with Ultrasonography

Gelişimsel Kalça Displazisi ve Ultrasonografinin Erken Tanıda Önemi

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ABSTRACT

Aim: The prognosis for paediatric patients undergoing treatment for hip dysplasia is generally favourable, particularly when treated non-surgically following early diagnosis. However, when open surgical reduction is required, short-term results may be less favourable. The present study aims to investigate the risk factors leading to developmental hip dysplasia and evaluate the diagnostic value of hip ultrasonography in light of current literature.

Material and Method: This research was conducted retrospectively as part of a thesis study carried out in the Radiology Clinic of Istanbul Haydarpaşa Numune Hospital (1997-1998). The study population comprised 246 newborns (170 girls, 76 boys; total 492 hips) who underwent routine screening through orthopedic physical examination, or did not undergo such an examination. Standard and dynamic ultrasonography methods were utilised for evaluation. Cases with high suspicion or those meeting the definition of a dislocated hip were subjected to radiographic imaging for further evaluation. Consequently, the study was unable to ascertain the sensitivity and specificity of ultrasonography in comparison to radiography. The age range of the subjects included in the study was from one month to nine months. Of the cases, 169 were under 3 months, and 77 were over 3 months old. Informed consent was obtained from the patients' families, and a detailed medical history was recorded. Patients who required follow-up were contacted for a follow-up examination after four weeks.

Results: In our study, immature hips were detected in 82 female infants (16.67%) and 20 male infants (4.06%). The frequency of dysplastic hips was found to be 24 cases (4.88%) in female infants and 2 cases (0.41%) in male infants, with statistically significant differences between genders for both immature ($p<0.03$) and dysplastic ($p<0.035$) hips. The risk of hip immaturity and dysplasia was higher in infants with a positive Ortolani-Barlow test and at least one or more risk factors.

Conclusion: Our findings suggest that the simultaneous use of ultrasonographic evaluation along with physical examination tests may contribute significantly to the diagnosis.

Keywords: Developmental hip dysplasia, ultrasonography, Ortolani-Barlow test

ÖZ

Amaç: Kalça displazisi tedavisi gören çocukların prognozu, özellikle erken tanı konularak cerrahi dışı yöntemlerle tedavi edildiklerinde oldukça iyidir. Ancak, açık cerrahi redüksiyon gerektiğinde kısa vadeli sonuçlar daha az yüz güldürücü olabilir. Bu çalışmada amacımız, gelişimsel kalça displazisine yol açan risk faktörlerini incelemek ve kalça ultrasonografisinin tanı değerini güncel literatür bilgileri ışığında değerlendirmektir.

Gereç ve Yöntem: Bu araştırma, İstanbul Haydarpaşa Numune Hastanesi Radyoloji Kliniği'nde gerçekleştirilen tez çalışması kapsamında retrospektif olarak yapıldı (1997-1998). Çalışmaya, rutin tarama amacıyla ortopedik fizik muayene yapılmış veya yapılmamış toplam 246 yenidoğan (170 kız, 76 erkek; toplam 492 kalça) dahil edilmiştir. Değerlendirmeler, standart ve dinamik ultrasonografi yöntemi kullanılarak gerçekleştirildi. Sadece yüksek şüphe duyulan ve disloke kalça tanımına uyan olgular radyografi ile kontrol edildi. Bu nedenle US'nin radyografiye göre duyarlılık ve özgüllüğü belirlenememiştir. Çalışmaya alınan en küçük bebek 1 aylık, en büyük bebek ise 9 aylıktı. Olguların 169'u 3 aydan küçük, 77'si ise 3 aydan büyüktü. Hastaların ailelerinden aydınlatılmış onam alındı ve gerekli anamnez bilgileri kaydedildi. Takip edilmesi gereken bebekler 4 hafta sonra kontrole çağrıldı.

Bulgular: Çalışmamızda, kız bebeklerde 82 olguda (%16,67), erkek bebeklerde ise 20 olguda (%4,06) immatür kalça tespit edildi. Displazik kalça sıklığı kız bebeklerde 24 olguda (%4,88), erkek bebeklerde ise 2 olguda (%0,41) bulundu. Hem immatür ($p<0,03$) hem de displazik ($p<0,035$) kalçalar açısından cinsiyetler arasındaki fark istatistiksel olarak anlamlı idi. Ortolani-Barlow testi pozitif olan ve en az bir veya daha fazla risk faktörüne sahip bebeklerde, kalça immatüritesi ve displazi riski artmakta idi.

Sonuç: Bulgularımız, fizik muayene testleri ile birlikte ultrasonografi incelemesinin eş zamanlı uygulanmasının tanıya önemli katkı sağlayabileceğini göstermektedir.

Anahtar Kelimeler: Gelişimsel kalça displazisi, ultrasonografi, Ortolani-Barlow testleri

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INTRODUCTION

Ultrasonography (US) is a valuable screening tool for diagnosing developmental dysplasia of the hip (DDH) in infants. Early detection of DDH allows for treatment without the need for surgical intervention. Consequently, radiologists must possess a comprehensive understanding of the sonographic anatomy of the normal infant hip, as well as proficiency in the screening and measurement techniques employed for DDH.

DDH is a dynamic condition in which the normal anatomical relationship between the femoral head and the acetabulum is disrupted due to various pathologies that can occur at birth or in the postnatal period. The condition manifests across a wide spectrum, ranging from a shallow or underdeveloped acetabulum (acetabular dysplasia) to a partial loss (subluxation) or complete loss (dislocation) of the relationship between the articular surfaces (1).

Whilst DDH can be effectively managed in the early stages using simple and cost-effective conservative methods, a delayed diagnosis is associated with a lower success rate, higher risks of complications and costs, and may necessitate complex surgical procedures that require considerable expertise (2, 3). Consequently, the early diagnosis and treatment of DDH are of paramount importance. This study investigates detailed aspects of the ultrasonographic early diagnosis of DDH and evaluates the utility of dynamic hip US.

MATERIAL AND METHOD

In the present study, a total of 492 hips from 256 newborns aged between one and nine months were examined. For the purpose of the examination, the infants were positioned in the lateral decubitus position, ensuring that the hip to be examined was positioned superiorly. The hip under examination was held in slight flexion, adduction, and internal rotation; gel was applied to the skin surface corresponding to the greater trochanter, after which the probe was positioned perpendicular to the hip to allow for acquisition of a frontal plane image (see **Figure 1**). Subsequent to the dynamic examination, angle measurements were performed with US and archived. The families of infants requiring follow-up were instructed to return for a control examination after four weeks. In addition, the radiographic films of patients who underwent X-rays were reviewed and the information was archived.

Seven reference groups with high risk for hip dislocation were determined:

1. Those with only a positive Ortolani-Barlow test.
2. Those born in a breech presentation.
3. Those with only a positive family history.
4. Those with a positive Ortolani-Barlow test and born in a breech presentation.
5. Those with both a positive Ortolani-Barlow test and a positive family history.
6. Those with a positive family history and born in a breech presentation.
7. Those with a positive Ortolani-Barlow test and a positive family history, and also born in a breech presentation.

A numerical and proportional comparison of these groups was conducted according to the ultrasonographic types. The newborns in the patient group and the reference groups were separately evaluated both numerically and proportionally according to the Graf-modified morphological classification (**Table 1**)(4). Furthermore, a dynamic ultrasonographic assessment was performed. In the dynamic US, the configuration of the acetabulum was evaluated using coronal/flexion imaging. The imaging plane in which the acetabulum was best visualised was selected; this was achieved by ensuring that the iliac line was seen in a straight alignment at the midline.

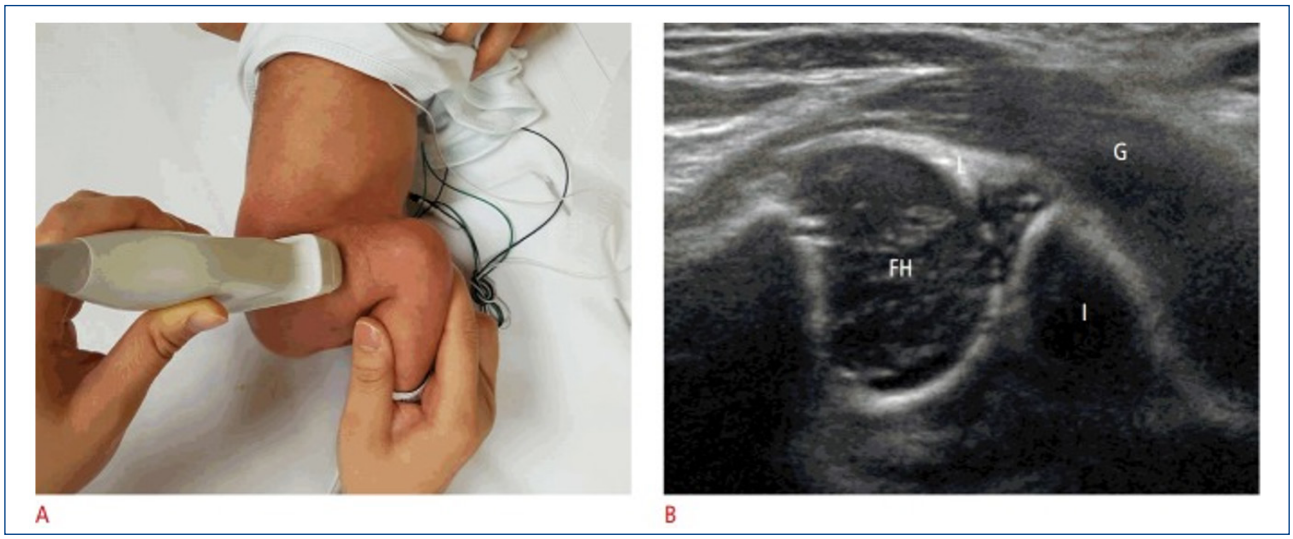

Figure 1. A-The infant's hip and knee are positioned in 90° flexion. **B-**Gluteal Muscles (G), Femoral Head Cartilage (FH), Ischium (I), Labrum (L).

Table 1: Graf images the hip joint using US, measures specific angles, and classifies the hip into four fundamental types based on these measurements.

Type	Description	Alfa angle (°)	Beta angle (°)	Age
Type I	Normally developed hip	≥60°	≤55°	All ages
Type II a	Physiologically immature hip	50-59°	>55°	≤3 months
Type II b	Delayed maturation	50-59°	>55°	>3 months
Type II c	Dysplastic hip; risk of subluxation	43°-49°	>70°	All ages
Type II d	Dysplastic hip; subluxation present	43°-49°	>77°	All ages
Type III	Subluxation or partial dislocation; femoral head partially displaced	<43°	>77°	All ages
Type IV	Complete dislocation; femoral head completely displaced	<43°	>77°	All ages

RESULTS

A total of 492 hips from 246 newborns were examined. Of these newborns, 170 (69.11%) were female and 76 (30.89%) were male. Of the newborns, 20 males and 34 females (a total of 54) were delivered via caesarean section. With regard to maternal parity, 120 mothers were primiparous (48.78%) and 126 were multiparous (51.22%). Furthermore, a breech presentation was observed in 130 newborns (48 males and 82 females), corresponding to 52.84%. In 66 newborns (54 females and 12 males), a positive family history was recorded (26.83%). On the left side, 40 hips were classified as immature (8.13%) and 6 as dysplastic (1.22%), while on the right side, only 6 hips were identified as immature (1.22%) (**Table 2**, **3**).

Table 2: Distrubition of hip US results according to gender (%).

Type	Ia	Ib	Iıa	IIc	IId	III	IV	Total
Female patient	122 24.80%	112 22.76%	94 19.1%	8 1.6%	-	4 0.8%	-	340 69.1%
Male patient	80 16.26%	50 10.16%	22 4.47%	-	-	-	-	152 30.8%
Total	202 41.06%	162 32.92%	116 23.5%	8 1.6%	-	4 %0.8	-	492 100%

Table 3: Numerical and proportional distribution of newborns delivered via normal spontaneous birth (NSB) and cesarean section according to sonographic types (%).

Types	Ia	Ib	Iıa	IIb	IIc	IId	III	IV	Total
NSB	150 30.49%	134 27.23%	88 17.89%	-	8 1.63%	-	4 0.81%	-	384 78.05%
Sectio	52 10.57%	28 5.69%	28 5.69%	-	-	-	-	-	108 21.95%
Total	202 41.06%	162 32.92%	116 23.58%	-	8 1.63%	-	4 0.81%	-	492 100%

As indicated by the extant literature, primiparous births have been identified as a risk factor in this study. Among the newborns of primiparous mothers, 78 cases (15.85%) were classified as having immature hips, and 6 cases (1.27%) were identified as having dysplastic hips. In comparison, the same values for multiparous births were 82 cases (16.66%) and 2 cases (0.41%), respectively. While the difference for immature hips was not statistically significant, the difference for dysplastic hips was found to be significant (p=0.015) (**Table 4**).

Table 4: Numerical and proportional distribution of ultrasonographic types in primiparous and multiparous births (%).

Types	Ia	Ib	Iıa	IIb	IIc	IId	III	IV	Total
Primipar	72 14.69%	80 16.26%	78 15.85%	-	6 1.27%	-	4 0.81%	-	240 48.78%
Multipar	130 26.42%	82 16.66%	38 7.73%	-	2 0.41%	-	-	-	252 51.22%
Total	202 41.06%	162 32.92%	116 23.58%	-	8 1.63%	-	4 0.81%	-	492 100%

In the left hips, immature cases were observed in 40 newborns (8.13%), and dysplastic cases were found in 6 newborns (1.22%). On the right side, only 6 cases of immature hips were detected (**Table 5**).

Table 5: Numerical and proportional distribution of cases with immaturity and dysplasia based on the affected side (%).

Morphology	Immature	Dysplastic
Left	40; 8.1%	6; 1.22%
Right	6; 1%	-
Bilateral	56İ 11%	20; 4.6%

In Group VII, which included newborns with Ortolani-Barlow positivity, a family history of DDH in first-degree relatives, and breech presentation at birth, 20 hip cases (4.06%) were examined. Among these, 4 cases (1.63%) were identified as immature, and 5 cases (2.03%) were classified as dysplastic.

In Group I, consisting of 122 hip cases (26.83%) with only Ortolani-Barlow positivity, 34 cases (6.91%) were found to be immature.

Among the 98 hip cases (19.92%) classified as normal, 74 cases were categorized as Type Ib, indicating a physiological maturation delay.

In Group IV, which comprised infants exhibiting positive Ortolani-Barlow signs and a family history of the condition, 30 of the 64 hip cases were identified as immature (6.1%), and 4 were dysplastic hips (0.81%). In Group V, a total of 52 hips were examined (10.57%), of which 36 were immature (7.3%) and 2 were dysplastic (0.41%). In neonates exhibiting positive Ortolani-Barlow signs, accompanied by one or more risk factors, there is an elevated prevalence of hip immaturity and dysplasia.

In Group II, consisting of babies born with breech presentation, no cases of immaturity or dysplasia were observed in 164 hips (33.33%). A similar observation was made in Group III, which included babies with a positive family history in first-degree relatives, with no cases of immaturity or dysplasia recorded in 48 hips (9.76%). In Group VI, comprising infants born in breech presentation with a positive family history in first-degree relatives, no cases of immaturity or dysplasia were identified in 12 hips (4.06%) (see **Tables 6** and **7**).

Table 6: Numerical and Proportional Distribution of Hip Cases in Reference Groups According to Morphological Classification (%).

Morphological Classification	Normal	Immatue	Dysplastic	Total
Group I	98 19.92%	34 6.91%	-	132 26.83%
Group II	164 33.33%	-	-	164 33.33%
Group III	48 9.76%	-	-	48 9.76%
Group IV	30 6.10%	28 5.69%	6 1.22%	64 13.01%
Group V	10 2.03%	32 6.50%	10 2.03%	52 10.57%
Group VI	12 2.44%	-	-	12 2.44%
Group VII	2 0.40%	8 1.63%	10 2.03%	20 4.06%
Total Groups	364 73.98%	102 20.73%	26 5.29%	492 100%

Table 7: Numerical and percentage distribution of hip cases according to ultrasonographic types in reference groups (%).

Types	Ia	Ib	IIa	IIb	IIc	IId	III	IV	Total
Group I	26 5.2%	72 14.63%	34 6.6%	-	-	-	-	-	132 26.83%
Group II	132 26.83%	32 6.2%	-	-	-	-	-	-	164 33.33%
Group III	26 5.28%	22 4.47%	-	-	-	-	-	-	48 9.76%
Group IV	14 2.85%	16 3.25%	30 6.1%	-	4 0.81%	-	-	-	64 13.01%
Group V	-	10 2.03%	36 7.3%	-	2 0.41%	-	4 0.8%	-	52 10.57%
Group VI	4 0.81%	10 1.63%	-	-	-	-	-	-	12 2.44%
Group VII	-	2 0.41%	16 3.2%	-	2 0.41%	-	-	-	20 4.06%
Total Groups	202 41.06%	162 32.92%	116 23%	-	8 1.63%	-	4 0.8%	-	492 100%

DISCUSSION

In recent years, two hip US methods have been employed: the static technique developed by Graf and the dynamic and real-time method developed by Harcke et al. (5). The US examination first applied by Austrian orthopaedic surgeon Graf in 1978 has gained significant importance as the most valuable method for diagnosing DDH in the first three months of life, due to its many advantages compared to other methods (6, 7).

Harcke et al. developed a combined static and dynamic US method based on a supine position and a lateral approach (8). This method is fundamentally a dynamic examination technique, comprising sagittal, coronal, and axial images while the hip is in neutral and flexion positions. The method is a dynamic four-stage procedure, both with and without the Barlow stress test. The method is centred on the position of the femoral head during both rest and stress testing, with additional consideration given to the configuration of the acetabular bone and cartilage borders. The method is primarily subjective in nature and does not incorporate quantitative measurements. In contrast to the aforementioned methods, Terjesen's approach encompasses both qualitative and quantitative elements, thereby offering a more comprehensive framework for analysis (9). The Suzuki method was first described in the early 1990s by Shigeo Suzuki and colleagues (10). In this method, while the patient is in a supine position with the hips in extension, a wide linear probe is placed on both the pubic bones and the femoral heads. In the event of a dislocation being detected, the examination continues in flexion and abduction. The femoral metaphysis is utilised to delineate the femoral head in the abduction and flexion positions. It has been documented that this method allows for the examination of both hips using abduction support or casting.

The Terjesen method was first described in the late 1980s by Terje Trejesen and colleagues from Oslo, Norway (11). The examination is conducted in a lateral position with the patient in a supine posture, and the probe can be linear or sectorial (12,13). The method incorporates both numerical measurements and qualitative descriptions. The femoral head coverage value (FHC) is defined as the percentage of the entire cartilaginous femoral head that is covered by the acetabular bony rim. The lower normal limit for FHC is 50% in babies older than one month. However, it is important to note that this parameter can only be used during the first year of life, as ossification of the femoral head after this age renders the acetabular fossa unvisualizable.

Two significant issues require further elucidation with respect to the methodology of newborn hip screening programmes (14). Firstly, it is necessary to ascertain whether clinical screening is sufficient to detect DDH in all newborns. If the former is deemed to be the case, then the question must be posed as to whether universal hip screening is required for all newborns, or whether it should be limited to high-risk babies as part of a selective screening process. The response to the aforementioned inquiries appears contingent upon the precision of the clinical evaluation and the expertise of the evaluators.

Previous studies have indicated that a dedicated and experienced clinician can achieve a high degree of success in detecting pathological hips through clinical examination (15). Conversely, it has been documented that the probability of missing all pathological hips with clinical screening alone is 2.6 per 1,000, with half of these being subluxated or dislocated hips (16). A 2013 study found that the findings from clinical and US screening groups were mostly similar (17).

The immature hip is characterized by the absence of sufficient insertion of the femoral head into the acetabulum, the hip socket. This is not a congenital defect; rather, it is a delayed developmental maturation process. This developmental abnormality generally resolves spontaneously, leading to enhanced stability of the femoral head within the acetabulum. Ultrasonography is a useful diagnostic modality, as it allows for visualization of the femoral head's proximity to the upper part of the acetabulum, which is indicative of immaturity. It is imperative to note that the dysplastic hip constitutes a permanent developmental abnormality, which, if left untreated, can lead to grave complications (18). It has been demonstrated that Graf type IIc and worse hips can be detected through clinical examination by experienced hands; however, the risk of missing Graf type IIa and IIb hips is significantly higher when relying solely on clinical examination (19).

It was previously reported that approximately 25% of hip prostheses in individuals under the age of 40 had underlying DDH etiology (20). This significant finding underscores the importance of newborn hip screening. A recent decision analytic model has highlighted the importance of clinical and US newborn hip screening in preventing late degenerative hip arthritis (21).

In a further prospective randomised study, the rate of late-diagnosed DDH per 1,000 live births was 0.13 in the universal screening group and 0.65 in the selective screening group (15). The estimated prevalence of DDH in Turkey ranges from 0.5% to 1.5% (21). The incidence identified through hip US screening ranges from 0.86% to 17% (23, 24).

The optimal time for US screening is also a subject of debate. A recent ultrasound study revealed that only 9% of hips diagnosed as Graf type IIa or worse within the first three days of life would remain abnormal and require treatment during the follow-up period (25). Conversely, another study demonstrated that 99.6% of Graf type I hips at one month of age would maintain their classification as type I at three months (26). For neonates exhibiting clinically unstable hips or risk factors, such as family history or breech presentation, the recommended time for US examination is within the first week of life. For the remaining neonates, the recommended time is between four and six weeks (27).

Bache et al. reported that only 20% of patients with abnormal ultrasound findings at 6 weeks had unstable hips on initial examination (28). Tönnis has stated that, given the capacity of ultrasound to detect a range of pathologies that would not be revealed through alternative clinical procedures, it is essential that all newborns undergo screening (29).

A study by Çakır et al. identified breech presentation, being a first-born girl, multiple pregnancy and oligohydramnios as the most common risk factors (30). In a subsequent study by Chan et al., breech presentation, oligohydramnios, female sex, and primiparity were identified as risk factors for DDH (30). A meta-analysis by De Hundt et al. further identified breech presentation, female sex, a positive family history, and the presence of hip clicks during physical examination as the strongest risk factors for DDH (32).

The present study reveals that the prevalence of DDH exhibits significant disparities based on sex ($p<0.03$). The incidence of hip immaturity and dysplasia is higher in girls compared to boys ($p<0.035$). The study found that caesarean delivery was not a significant risk factor ($p>0.005$). In a related study by Uslu et al., no statistically significant difference in dysplastic hips was observed between infants delivered by cesarean section and those delivered vaginally (33).

Furthermore, the incidence of DDH has been observed to be higher in babies born to primiparous mothers than in those born to multiparous mothers. Hip immaturity and dysplasia are frequently bilateral, with pathology most commonly observed in the left hip. In a study published in 2024, Keleş Alp and colleagues reported the detection of bilateral DDH in 12 out of 28 cases (34).

Furthermore, the likelihood of hip immaturity and dysplasia increases in newborns exhibiting positive Ortolani-Barlow signs and at least one risk factor. Consequently, under appropriate conditions, it is recommended that all newborns undergo hip ultrasound in conjunction with a physical examination.

Hip US has been shown to have a specificity and sensitivity of over 90% in diagnosing DDH (35, 36). There is a divergence of opinion regarding the optimal timing for screening, with the sixth week postpartum being proposed as a period when minor temporary anomalies of the hip may spontaneously resolve, and permanent anomalies can be detected in a timely manner (37). Barlow has suggested that 60% of hips with instability detected at birth will resolve within the first week, and 88% will resolve within two months (38).

CONCLUSION

The diagnosis of DDH in newborns and infants within the first three months of life is challenging to ascertain through clinical examination alone. In cases of dysplastic

or subluxated hips, there is a possibility of a missed diagnosis, and normal hips may be misinterpreted as abnormal. In regions experiencing insufficient socioeconomic development, the challenges associated with diagnosis are further compounded by delays in diagnosis. A delayed diagnosis can complicate treatment, creating challenges for both orthopaedic surgeons and patients. Treatment for DDH diagnosed in older ages is generally not very successful. Therefore, the primary objective should be to make the diagnosis at an age where anatomical healing can still be achieved. Hip US is recommended during the first month of life. An effective hip US method should include simple, accurate, quantitative, and consistent definitions to obtain a correct diagnosis and properly manage hip dysplasia. The Graf method has been shown to meet all these requirements, making it suitable for accurately defining hip morphology and effectively managing the newborn hip joint.

In newborns exhibiting positive Ortolani-Barlow tests and at least one or more risk factors, the risk of hip immaturity and dysplasia is increased. The concurrent utilisation of physical examination tests in conjunction with ultrasound has been posited as a means to facilitate more precise diagnosis.

ETHICAL DECLARATIONS

Ethics Committee Approval: This research was conducted retrospectively as part of a thesis study carried out in the Radiology Clinic of Istanbul Haydarpaşa Numune Hospital (1997-1998).

Informed Consent: Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process: Externally peer-reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

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