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Is experience alone sufficient to diagnose developmental dysplasia of the hip without the bony roof (alpha angle) and the cartilage roof (beta angle) measurements?

A diagnostic accuracy study

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Abstract

In the Graf method of hip ultrasonography, the diagnosis of the infantile hip with developmental dysplasia of the hip (DDH) is strictly dependent on the bony roof (alpha angle) and the cartilage roof (beta angle) measurements. In this study, we investigated whether the infant hip could be diagnosed with DDH solely by evaluating ultrasound images obtained in the standard plane, without bony roof and cartilage roof measurements, in respect to different professional experience levels.

Two hundred ten hip ultrasounds were randomly selected from patients who presented to our hospital for DDH screening. A total of 6 ultrasound images were obtained for each hip. The hip morphology evaluations were made without the bony roof and the cartilage roof measurements by 2 orthopedic surgery residents; 2 orthopedic surgery specialists, trained in the diagnosis and the treatment of the DDH; and 2 pediatric orthopedic surgery professors, highly experienced in the diagnosis and treatment of DDH. After hip morphology evaluations, the bony roof and the cartilage roof measurements were obtained and hip type evaluations were made by the same raters, according to the Graf method of hip ultrasonography.

The highest intraobserver agreements between the hip maturity evaluation before and the hip type evaluation after measurements were .676 ($P < .001$) and .577 ($P < .001$) in professors 2 and 1, respectively, and the lowest agreements were .185 ($P < .01$) and .289 ($P < .001$) in specialist 1 and resident 2, respectively.

The diagnosis of the infant hip as DDH could not be made solely by evaluation of the ultrasound images obtained in the standard plane without the bony roof and the cartilage roof measurements. The bony roof and the cartilage roof measurements were obligatory for the diagnosis of the infant hip as DDH, even in the very experienced pediatric orthopedic surgeons.

Level of evidence: 2.

Abbreviations: DDH = developmental dysplasia of the hip, fellow = Dursun AK, MD. The practitioner in the fellowship training program in the Department of Orthopedic Surgery, Fatih Sultan Mehmet Education and Research Hospital, Istanbul, Turkey, ICC = intraclass correlation coefficient, prof1 = Professor 1. Hasan Hilmi Muratli, MD. Professor in the Department of Orthopedic Surgery, Fatih Sultan Mehmet Education and Research Hospital, Istanbul, Turkey. Chairmen of the Turkish Pediatric Orthopedic Surgery Association, prof2 = Professor 2. Mehmet Mufit Orak, MD. Professor in the Department of Orthopedic Surgery, Fatih Sultan Mehmet Education and Research Hospital, Istanbul, Turkey, res1 = Resident 1. Ilyas Aslan, MD. Resident in the Department of Orthopedic Surgery, Fatih Sultan Mehmet Education and Research Hospital, Istanbul, Turkey, res2 = Resident 2. Ozgun Karakus, MD. Resident in the Department of Orthopedic Surgery, Fatih Sultan Mehmet Education and Research Hospital, Istanbul, Turkey, spe1 = Specialist 1. Ozgur Karaman, MD. Specialist in the Department of Orthopedic Surgery, Fatih Sultan Mehmet Education and Research Hospital,

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The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethical approval was obtained by Kayseri Erciyes University Hospital ethics committee. Consent to participate was obtained from the parents of the participants.

Written informed consent for publication of their clinical details and/or clinical images was obtained from the patient. A copy of the consent form is available for review by the editor of this journal.

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1. Introduction

Developmental dysplasia of the hip (DDH) is a common hip disease. It results from an abnormal relation between the head of the femur and the acetabulum and manifestations range from subtle dysplasia of the acetabulum to obvious dislocation of the femoral head.[1–3] Treatment objectives include concentric reduction of the hip and good acetabular coverage of the femoral head.[4,5]

Early diagnosis is the key for successful treatment. Most of the bony parts of the acetabulum and femoral head remain cartilaginous during the first few months of life, which limits the use of plain radiographs for the diagnosis of DDH in infants younger than 6 months of age.[3,6] Due to this limitation of roentgenograms and the concern of ionizing radiation exposure in infants, hip ultrasonography is currently the most common method used in the diagnosis of DDH in the first 6 months of life.[6] Graf, Harcke, Terjersen, and Suzuki have developed hip ultrasonography methods for the evaluation of the infantile hip.[7–10] Of these, the Graf method is probably the most commonly used because of its high rate of sensitivity, specificity, and reproducibility.[6]

In the Graf method, the diagnosis, classification, and follow-up treatment of infantile DDH strictly depends on the bony roof angle (alpha angle) and cartilage roof angle (beta angle) measurements.[6,7] Many radiological modalities used in orthopedic surgery do not necessitate precise measurements for the diagnosis of a suspected pathological condition; instead, diagnosis is made by detailed physical examination of the patient, with careful evaluation of radiological images. However, classification of the pathological condition and treatment decisions are reliant on measurements obtained on radiological images after the diagnosis.[11–15] Likewise, careful evaluation of high-quality roentgenograms of a patient who suffers from forearm pain after a fall are generally sufficient for diagnosing fracture of the forearm bones. However, surgical versus conservative treatment decisions are usually based on the precise measurement of the angulation and/or displacement on roentgenograms after closed reduction of the fracture.[16]

In the present study, we investigated whether this kind of relationship exists with ultrasonography of the infantile hip. We evaluated the diagnostic accuracy of the infant hip as DDH made by careful evaluation of ultrasound images obtained in the standard plane, without bony roof, and cartilage roof measurements, in respect to different professional experience levels.

2. Methods

This study was approved by the Kayseri Erciyes University Hospital ethics committee and signed consent was obtained from the parents/guardians of all the study participants. Two hundred ten hip ultrasounds were randomly selected from patients (mean age of 11 weeks, range 3–21 weeks) who presented to our hospital for DDH screening. All clinical examinations and ultrasound screenings were performed by the same pediatric orthopedic surgery fellow. All ultrasound examinations were performed via a Sonoline G60S ultrasound system (SIEMENS, Erlangen, Germany) using a 7.5 MHz linear probe, according to the Graf method of hip ultrasonography. Infants were placed on the hip ultrasound table in a lateral decubitus position. During ultrasound screening, images on the monitor were frozen to determine if they were in the standard plane; when the standard plane was confirmed, 6 copies of the image were printed. The 6 images were evaluated by 2 orthopedic surgery residents (res1 and res2); 2 orthopedic surgery specialists (spe1 and spe2), trained in the diagnosis and treatment of DDH; and 2 pediatric orthopedic surgery professors (prof1 and prof2), highly experienced in the diagnosis and treatment of DDH (Table 1). All of the raters had completed a Graf method training program.

Each rater evaluated the ultrasound images in the same order. First, the rater evaluated whether the ultrasound image was in the standard plane. If the rater decided that the ultrasound image was

Table 1

The age, sex, and the experience in orthopedic surgery of the raters[*].

	Age (yr)	Sex	Experience in orthopedic surgery (yr)[†]
res1	29	Male	4
res2	28	Male	3
spe1	38	Male	13
spe2	35	Male	10
prof1	56	Male	24
prof2	53	Male	28

[*] res1, res2, spe1, spe2, prof1, and prof2 correspond to resident 1, resident 2, specialist 1, specialist 2, professor 1, and professor 2, respectively.
[†] Includes the residency program of the practitioner.

Table 2

The alpha and beta angle measurements according to the raters[*].

	Alpha angle (°) mean ± std deviation median (minimum – maximum)	Beta angle (°) mean ± std deviation median (minimum – maximum)
res1	67.106 ± 7.199 70.0 (42.0 – 82.0)	56.462 ± 5.594 55.0 (45.0 – 75.0)
res2	67.0 ± 7.130 70.0 (42.0 – 82.0)	56.462 ± 5.589 55.0 (45.0 – 75.0)
spe1	67.096 ± 7.207 70.0 (42.0 – 82.0)	56.548 ± 5.614 55.0 (45.0 – 75.0)
spe2	66.196 ± 6.134 67.0 (44.0 – 78.0)	45.362 ± 8.716 44.0 (30.0 – 71.0)
prof1	63.814 ± 6.845 65.0 (36.0 – 80.0)	61.050 ± 6.220 60.0 (45.0 – 85.0)
prof2	66.091 ± 7.051 67.0 (38.0 – 77.0)	60.146 ± 7.872 60.0 (40.0 – 90.0)

[*] res1, res2, spe1, spe2, prof1, and prof2 correspond to resident 1, resident 2, specialist 1, specialist 2, professor 1, and professor 2, respectively.

Table 3

Hip maturity evaluations prior to the measurements and the hip type evaluations after the measurements according to the raters*.

	Hip maturity evaluations prior to the measurements			Hip type evaluations after the measurements					
	Mature	Immature	Total	Type 1	Type 2	Type D	Type 3	Type 4	Total
res1	183	25	208	186	21	0	1	0	208
res2	177	31	208	186	21	0	1	0	208
spe1	184	21	205	182	21	0	2	0	205
spe2	176	28	204	182	18	0	4	0	204
prof1	186	18	204	177	26	1	0	0	204
prof2	178	30	208	185	19	1	3	0	208

* res1, res2, spe1, spe2, prof1, and prof2 correspond to resident 1, resident 2, specialist 1, specialist 2, professor 1, and professor 2, respectively.

in the standard plane, the rater classified the hip as mature or immature solely by examining the image. According to the Graf method, the mature hip corresponds to type 1 hip and the immature hip corresponds to types 2, D, 3, and 4 hips. Thereafter, measurements of the bony roof (alpha angle) and the cartilage roof (beta angle), and determination of the hip type were performed. All measurements were made with a goniometer, according to the Graf method.[7] All raters were blinded to the evaluation results of the others. The intra and interobserver agreements of the classifications and measurements were evaluated statistically.

2.1. Statistical analysis

Shapiro–Wilk's test was used to assess the normality of distributions of the continuous variables. As distributions were not normal, agreements between measurements were analyzed by Spearman rho correlation coefficients. Interrater reliabilities and agreements were evaluated by Cohen Kappa statistics for discrete variables. Data analyses were performed using the Statistical Package for the Social Sciences, version 19.0 (IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY: IBM Corp). A P value $<.05$ was considered statistically significant. The results of statistical analysis were expressed as number and ratio of observations (n, %), mean ± standard deviation (mean ± SD), median and minimum – maximum values [M (min – max)].

Table 4

Hip maturity evaluations in respect to the hip types according to the raters*.

	Type 1	Type 2, D, 3, and 4	Total
res1			
Mature	170	13	183
Immature	16	9	25
Total	186	22	208
res2			
Mature	165	12	177
Immature	21	10	31
Total	186	22	208
spe1			
Mature	167	17	184
Immature	15	6	21
Total	182	23	205
spe2			
Mature	169	7	176
Immature	13	15	28
Total	182	22	204
prof1			
Mature	173	13	186
Immature	4	14	18
Total	177	27	204
prof2			
Mature	174	4	178
Immature	11	19	30
Total	185	23	208

* res1, res2, spe1, spe2, prof1, and, prof2 correspond to resident 1, resident 2, specialist 1, specialist 2, professor 1, and professor 2, respectively.

3. Results

Res1, res2, spe1, spe2, prof1, and prof6 evaluated 2, 2, 5, 6, 6, and 2 images as not in the standard plane, respectively; thus, these were excluded from their classifications. The mean alpha and beta angle measurements according to the raters are expressed in Table 2. The hip maturity evaluations prior to the measurements and the hip type evaluations after the measurements are shown in Tables 3 and 4, respectively.

The intraobserver agreements between the hip maturity evaluation prior to the measurements and the hip type evaluation after the measurements are expressed in Table 5. The highest agreements were .676 ($P<.001$) and .577 ($P<.001$) in prof2 and prof1, respectively and the lowest agreements were .185 ($P<.01$) and .289 ($P<.001$) in spe1 and res2, respectively.

The interobserver agreements of hip morphology evaluations before and hip type evaluation after measurement are expressed in Table 6. The highest agreements were .808 ($P<.001$) in between res1 and res2 in the evaluation of the hip maturity and .892 ($P<.001$) in between res1 and res2 in the evaluation of the hip type. The lowest agreements were .177 ($P<.01$) in between spe1 and spe2 in the evaluation of the hip maturity and .486 ($P<.001$) in between prof1 and prof2 in the evaluation of the hip type.

4. Discussion

Graf used hip ultrasonography to develop a protocol for the early diagnosis of DDH, which has become widely accepted in many

Table 5

The intraobserver correlations between the hip maturity evaluation prior to the measurements and the hip type evaluation after the measurements*.

	res1	res2	spe1	spe2	prof1	prof2
Intraobserver morphology vs hip type	.305 $P<.001$	.289 $P<.001$	.185 $P<.01$	.545 $P<.001$	.577 $P<.001$	.676 $P<.001$

* res1, res2, spe1, spe2, prof1, and prof2 correspond to resident 1, resident 2, specialist 1, specialist 2, professor 1, and professor 2, respectively.

Table 6

The interobserver correlations of the hip morphology evaluations prior to the measurements and hip type evaluations after the measurements in respect to the different experience levels*.

	res1 – res2	spe1 – spe2	prof1 – prof2
Hip maturity	.808	.177	.299
	$P < .001$	$P < .01$	$P < .01$
Hip type	.892	.575	.486
	$P < .001$	$P < .001$	$P < .001$

* res1, res2, spe1, spe2, prof1, and prof2 correspond to resident 1, resident 2, specialist 1, specialist 2, professor 1, and professor 2, respectively.

Table 7

Intraclass correlation coefficients between the hip maturity evaluation prior to the measurements and the hip type evaluation after the measurements according to the raters*.

ICC	Comment	Rater
<.40	Poor	res1, res2, and spe1
.40 to .59	Fair	prof1 and spe2
.60 to .74	Good	prof2
.75 to 1.00	Excellent	

* res1, res2, spe1, spe2, prof1, and prof2 correspond to resident 1, resident 2, specialist 1, specialist 2, professor 1, and professor 2, respectively.

countries for DDH screening. Although many techniques have been described, the Graf method may be the most commonly used approach for evaluating the infantile hip.[6,7–10]

In this study, we investigated whether the diagnosis of infantile DDH could be made solely by evaluating ultrasound images obtained in the standard plane, in respect to different professional experience levels. Ultrasound screenings of infant hips might be more practical and less time consuming if DDH could be diagnosed with a high degree of accuracy from ultrasound images without precise measurements. To the best of our knowledge, this is the first study to investigate the accuracy of ultrasound image evaluations obtained in the standard plane, without bony roof and cartilage roof measurements, for the diagnosis of infantile DDH.

Intraobserver agreements between the hip maturity evaluation prior to the measurements and the hip type evaluation after the measurements aligned as prof2 (.676; $P < .001$), prof1 (.577; $P < .001$), spe2 (.545; $P < .001$), res1 (.305; $P < .001$), res2 (.289; $P < .001$), and spe1 (.185; $P < .01$) (Table 5). The Graf method of infantile hip ultrasonography is usually standardized; therefore, the experience and skill of the examiner are of little importance after a comprehensive education program.[17] However, the accuracy of hip maturation evaluations without bony roof and cartilage roof measurements may depend on the experience and skill of the examiner. In our study, prof1 and prof 2, who had the highest professional experience levels in diagnosing and treating DDH, also had the highest intraobserver agreements among the raters. The alignment in intraobserver agreements was probably due to the professional experience and skill levels of the raters.

The intraobserver agreements between the hip maturity evaluation prior to the measurements and the hip type evaluation after the measurements of the raters was good for prof2, fair for prof1 and spe2, and poor for res1, res2, and spe1, according to the intraclass correlation coefficient (ICC) (Table 7).[18,19] The accuracy of the evaluations in distinguishing normal and pathological hips, without bony roof and cartilage roof measurements, was very low, even in the very experienced prof1 and prof2 raters whose ICCs were fair and good, respectively. The bony roof and the cartilage roof measurements appear obligatory for the diagnosis of infantile DDH, as well as for its classification and follow-up treatment, even for very experienced pediatric orthopedic surgeons.

Interobserver agreements of hip morphology evaluations prior to measurements and hip type evaluations after measurements, in respect to different professional experience levels, are expressed in Table 6. The highest agreements were .808 ($P < .001$) between res1 and res2 in the evaluation of hip maturity and .892 ($P < .001$) between res1 and res2 in the evaluation of hip type. In the current study, the specialists had studied the Graf training program a long time ago; however, the residents had recently received their certifications in the Graf method. Moreover, the specialists may have interpreted information according to their clinical experience, whereas the residents may have used information taught in the training program without interpretation. These factors might explain the high interobserver agreements among the resident raters.

The diagnosis of the infant hip as DDH could not solely be made by careful evaluation of the ultrasound images obtained in the standard plane. The bony roof and cartilage roof measurements were obligatory for the diagnosis of infantile DDH, even for the very experienced pediatric orthopedic surgeons.

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Author contributions

OK and ASS participated in the design of the study and performed the statistical analysis. ASS conceived of the study, participated in its design and coordination, and helped to draft the manuscript. ASS and OK contributed to the writing and collecting of the data. All authors read and approved the final manuscript.

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