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Acetabular index and acetabular depth ratio in newborns and infants aged 6 months or less with the healthy development of hips

A retrospective cross-sectional study

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Abstract

Radiographic assessment of the hip may render critical in the diagnosis of developmental dysplasia of the hip (DDH) in newborns and infants aged ≤6 months. There is no complete dataset on the acetabular index (AI) and acetabular depth ratio (ADR) values in this age group. The objective of this study was to assess the AI and ADR values in newborns and infants aged ≤6 months with healthy development. A retrospective analysis was performed on pelvic radiographs of newborns and infants (≤6 months) between August 2020 and September 2021. There were 3000 children with pelvic radiographic imaging. Normal sonographic findings and radiographs without any structural deformity of the hip were inclusion criteria. A total of 1132 newborns and infants (2264 hips) were analyzed. Measurements of AI and ADR (ischium and pubic bone as landmarks for acetabular depth ratio A [ADR-A] and acetabular depth ratio B [ADR-B]) were performed. Correlation and intraclass correlation coefficient (ICC) values were calculated. Left-sided AI values were significantly higher than the right-sided AI values, except in infants aged 4 to ≤5 months ($P < .05$). ADR-B values differed significantly between male and female newborns and infants both in terms of the side of the hip measured and age ($P < .05$). AI values were fairly correlated with age (r = −0.286 for left and r = −0.254 for right) in the negative direction and with ADR-A (r = 0.449 and r = 0.469 for left and right) and ADR-B (r = 0.545 and r = 0.592 for left and right) in the positive direction. Inter-observer ICC was 0.845 to 0.989 (excellent) for AI, 0.534 and 0.904 (moderate to excellent) for ADR-A, and −0.014 and 0.774 (slightly good to good) for ADR-B. Intra-observer ICC was 0.811 to 0.996 (excellent) for AI, 0.575 to 0.98 (moderate to excellent) for ADR-A, and 0.023 to 0.954 (slightly good to excellent) for ADR-B. This study features the first complete data set of AI and ADR measurements, which are essential for pelvic radiographic imaging of hip dysplasia, in newborns and infants aged ≤6 months.

Abbreviations: ADR = acetabular depth ratio, ADR-A = acetabular depth ratio A, ADR-B = acetabular depth ratio B, AI = acetabular index, DDH = developmental dysplasia of the hip, ICC = interclass correlation coefficient, SD = standard deviation, USG = ultrasonography.

Keywords: developmental dysplasia of the hip, infants, newborns, radiography

1. Introduction

Clinical neonatal screening is critical in the early diagnosis and treatment of developmental dysplasia of the hip (DDH).[1,2] Ultrasonography (USG) is required to quantify hip dysplasia in infants younger than 4 months with risk factors such as familial history and female gender and born as a breech baby or a twin.[3–5] Pelvic anterior-posterior radiography has been used to obtain metric values of acetabular morphology and femoral head coverage in infants older than 6 months.[1,5,6]

Pelvic radiography was the only imaging modality used to image DDH before USG, which is currently regarded as the preferred imaging modality for infants younger than 4 months, became widespread.[7,8] Nevertheless, the reproducibility of the 2 dimention ultrasonographic screening outcomes has been a matter of debate

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Given the unanimity of the research data, written informed consent was not taken from the legal guardians of the newborns and infants included in this study.

The authors have no funding and conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

Ethical approval was obtained by Konya Necmettin Erbakan University Hospital ethics committee.

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considering operator dependency and poor reliability of intra- and inter-observer agreements.[5,8–11] The low quality of the sonograms has been shown in almost 1-third of the cases preventing the objective assessment of the degree of dysplasia.[12] Discrepancies between clinical and ultrasound examination findings are other challenging issues.[11] Additionally, accessibility to trained radiologists is still a problem for most health institutions in low-income countries.[13,14] Therefore, pelvic radiographs might be used to screen for the hip developmental dysplasia in selected cases.

Acetabular index (AI) and acetabular depth ratio (ADR) are the parameters showing the slope of the acetabular roof and borders of the acetabulum via the X-ray of the pelvis.[15,16] Tönnis et al[17,18] stratified the typical values of AI according to age, gender, and the side of the measurement in 1968 and 1976. In addition to being the standard imaging modality for hip dysplasia in infants older than 6 months, AI can also be used to assess hip morphology even in infants older than 4 months, given the initiation of femoral head ossification.[5,6] AI provides an objective parameter of acetabular dysplasia in terms of diagnosis and grading.[19] On the other hand, ADR has been proposed for the measurement of the width and depth of the acetabulum.[16] However, intra- and interobserver reliabilities of AI and ADR in evaluating the acetabular morphology have also been criticized.[19,20]

The standardized mean values of AI, along with their corresponding standard deviation (SD) values, have been developed for different age groups in Turkey, including 6 months to 8 years, 5 to 11 years, and 1 to 12 months.[15,21,22] Nevertheless, normative data on AI and ADR values in newborns and infants aged ≤6 months with healthy development are still lacking. Therefore, the objective of this study is to assess the AI and ADR values in newborns and infants aged ≤6 months with healthy development using pelvic radiographs and evaluate the intra-observer and inter-observer reliabilities of these AI and ADR measurements.

2. Methods

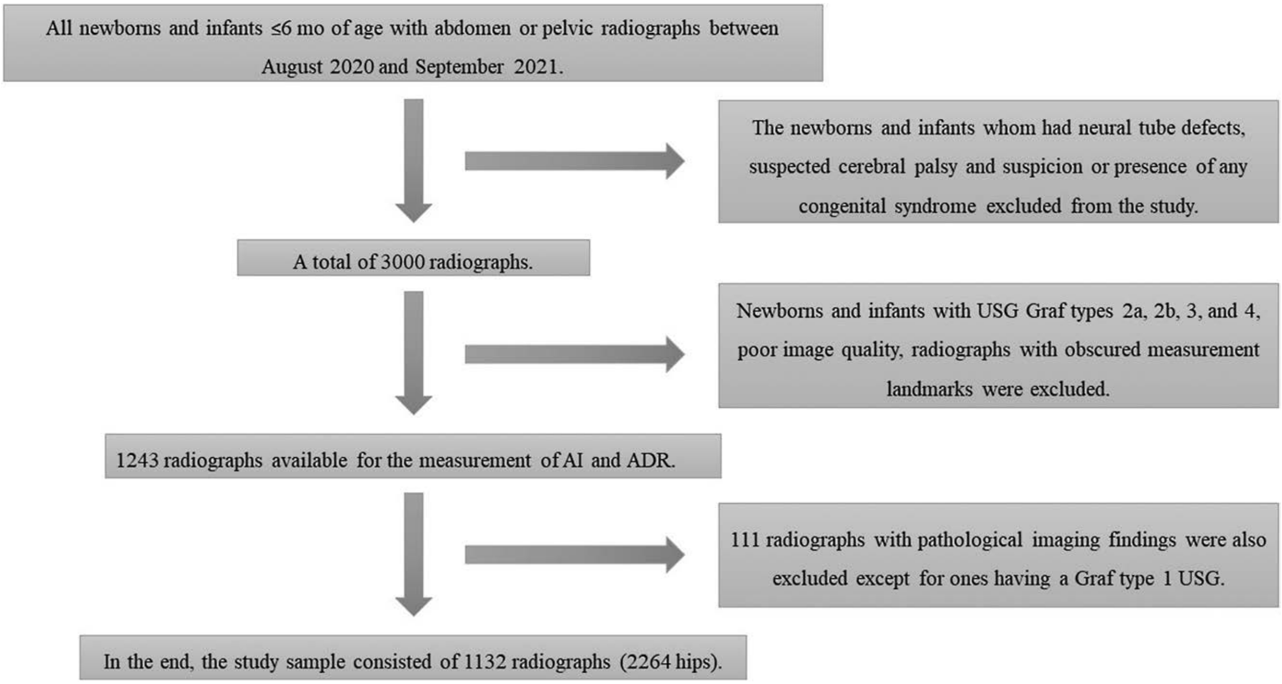
2.1. Study

The population of this retrospective study consisted of all newborns and infants with anterior-posterior pelvic, hip, lumber, or lower abdomen radiographs that were taken until 6 months of age between August 2020 and September 2021 at Konya City Hospital, Konya, Turkey. The reason behind performing an X-ray for the very young patient was out of the scope of the present study. The study protocol was approved by the local ethics committee (Necmettin Erbakan University Ethical Committee, 2021/3497). The study was conducted in accordance with the principles set forth in the Declaration of Helsinki. Given the unanimity of the research data, written informed consent was not taken from the legal guardians of the newborns and infants included in this study.

2.2. Data collection

Prior to the radiological evaluation, all of the newborns and infants included to the study were screened rigorously from the hospital database. The newborns and infants whom had neural tube defects, suspected cerebral palsy and suspicion or presence of any congenital syndrome excluded from the study in terms of the possibility of affecting the native hip development. The Picture Archiving Communications Systems of the hospital was used to assess the radiographs. A total of 3000 radiographs were evaluated. Newborns and infants with USG Graf types 2a, 2b, 3, and 4, poor image quality, radiographs with obscured measurement landmarks were excluded. Newborns and infants with USG Graf type 1 were included to the study whether they had an abnormal AI measurement on the pelvic X-ray based on the previous published data.[17]

The images with at most 1 cm left or right sacral projections from the midpoint of the symphysis pubis were also included in the study considering inevitable pelvic rotation. Of the remaining 1243 radiographs available for the measurement of AI and ADR, 111 radiographs with pathological imaging findings were also excluded.[17] The pathological imaging findings were the AI measurements above 35.8; 31.4 and 27.3 degrees in infants below 2 months, below 4 months and above 2 months; below 6 months and above 4 months respectively.[17] In the end, the study sample consisted of 1132 radiographs (2264 hips) (Fig. 1).



All newborns and infants ≤6 mo of age with abdomen or pelvic radiographs between August 2020 and September 2021.

The newborns and infants whom had neural tube defects, suspected cerebral palsy and suspicion or presence of any congenital syndrome excluded from the study.

A total of 3000 radiographs.

Newborns and infants with USG Graf types 2a, 2b, 3, and 4, poor image quality, radiographs with obscured measurement landmarks were excluded.

1243 radiographs available for the measurement of AI and ADR.

111 radiographs with pathological imaging findings were also excluded except for ones having a Graf type 1 USG.

In the end, the study sample consisted of 1132 radiographs (2264 hips).

Figure 1. The flow cart for the study population.

The Crystal Reports Viewer (CYR Consulting, Vienna, VA) software was used to measure the radiographs available on digital media. Three parameters, that is, AI, acetabular depth ratio A (ADR-A) (the depth ratio measured from the ischium), and acetabular depth ratio B (ADR-B) (the depth ratio measured from the pubic bone), were measured on each pelvic radiograph.[19] A single orthopedist surgeon with ten years of experience in pediatric orthopedic surgery (ASS) performed the AI and ADR measurements based on a standardized protocol described in the literature[1,22] (Fig. 2A and B). The subjects were grouped into 2 groups: infants aged 0 to 3 months, and infants aged 4 to 6 months. The subjects were also grouped according to the age below 1 months of age (≤1 month), below 2 months but above 1 month of age (<1–≤2 months), below 3 months but above 2 months of age (<2–≤3 months), below 4 months but above 3 months of age (<3–≤4 months), below 5 months but above 4 months of age (<4–≤5 months) and below 6 months but above 5 months of age (<5–≤6 months).

2.3. Reliability analysis

Thirty-five radiographs were randomly selected from each group for intra-observer and inter-observer reliability analyses. Three independent orthopedist physicians with 8 to ten years of experience blinded to other physicians' measurements were involved in the reliability analysis. The radiographs on the digital media were cleared of any patient-identifying information. The observers agreed on the standardized measurement technique in advance.[1]

The inter-observer agreement was determined based on the results of 3 different measurements, whereas the intra-observer agreement was determined based on the results of the measurements repeated after 3 weeks by observers who were blinded to the baseline results.

2.4. Statistical analysis

The descriptive statistics were expressed as mean ± SD values in the case of continuous variables determined to conform to the normal distribution, median and minimum-maximum values in the case of continuous variables determined not to conform to the normal distribution, and as numbers and percentage values in the case of categorical variables. Shapiro–Wilk, Kolmogorov-Smirnov, and Anderson-Darling tests were used to analyze the normal distribution characteristics of the numerical variables.

The paired samples t-test was used to evaluate the differences between the left and right-sided AI, ADR-A, and ADR-B measurements in the case of variables determined to conform to the normal distribution.

Spearman and Pearson Rho correlation coefficients were calculated to analyze the relationships between numerical variables depending on their normal distribution characteristics.

Reliability between and within observers was assessed using intraclass and interclass correlation coefficients (ICC), which fall between 0 and 1. ICC values were interpreted using the Landis and Koch classification. Accordingly, ICC values of 0 to 0.2 were interpreted as slight, 0.21 to 0.40 as fair, 0.41 to 0.60 as moderate, 0.61 to 0.80 as substantial/good, and 0.81 to 1.00 as almost perfect/excellent.[1]

Jamovi project 2.2.5.0 (https://www.jamovi.org) and JASP 0.16.1 (https://jasp-stats.org) software packages were used in the statistical analyses. The probability (*P*) statistics of ≤.05 were deemed to indicate statistical significance.

3. Results

The radiographs of a total of 1132 newborns and infants, of whom 635 (56.1%) were male and 497 (43.9%) female, were reviewed within the scope of this study. The median age of the study group at the time of imaging was 70.0 days (min. 0, max. 182).

The mean AI, ADR-A, and ADR-B values stratified to the left, and right sides are given in Table 1.

The distribution of the newborns and infants by age is shown in Table 2. There were significant differences between the left and right-sided measurements in the aged-based values of AI, ADR-A, and ADR-B ($P < .05$). The AI values of the left hip in male and female newborns and infants were significantly higher than those of the right hip in each age-based group, except for the infants aged 4 to ≤5 months ($P < .05$) (Table 2).

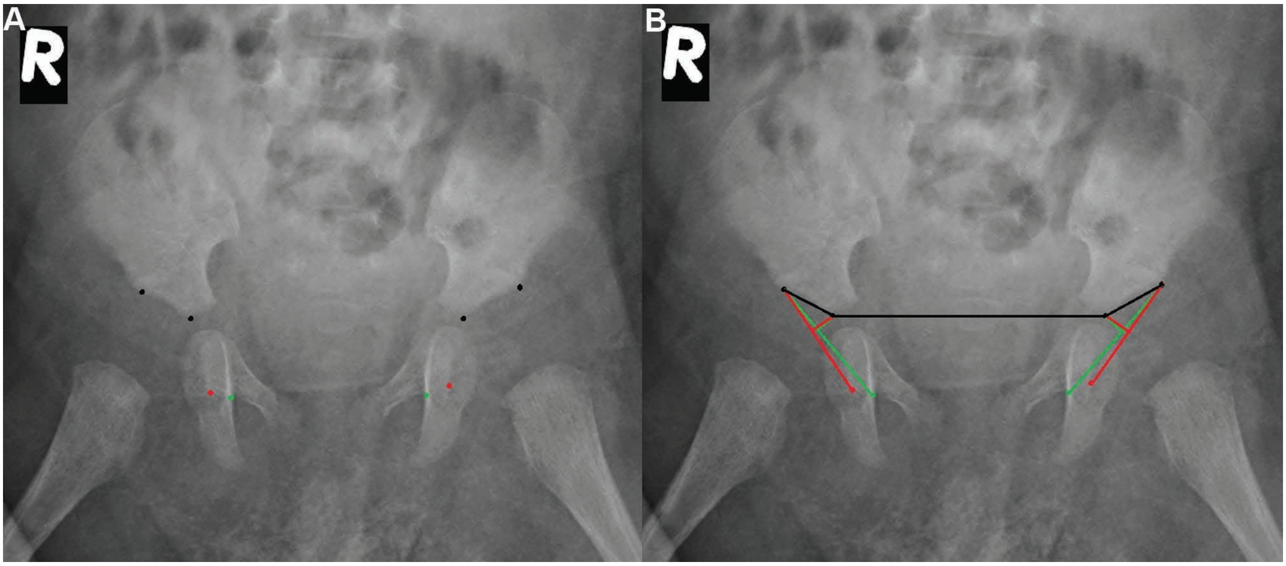


Figure 2. Reference points: Black points showing Y cartilage and the superolateral corners of the acetabulum, red points showing inferomedial corners of the pubic bone, and green points showing intersection of the pubic bone and the ischium (R: right side) (A) and measurements AI (black line), ADR-A (red lines), and ADR-B (green lines) on a plain film of a 42-d female infant (R: right side) (B). ADR-A = acetabular depth ratio A, ADR-B = acetabular depth ratio B, AI = acetabular index.

There was no significant difference between subgroups in ADR-A values, except that the left-sided ADR-A values were significantly lower than the right-sided ADR-A values in female newborns (*P* = .024) (Table 2). The left-sided ADR-B values were significantly lower than the right-sided ADR-B values in male infants aged <2 to ≤3 months and <5 to ≤6 months (*P* = .021 and *P* = .007, respectively). In female infants, the left-sided ADR-B values were significantly lower than the right-sided ADR-B values in the < 2 to ≤3 months, <4 to ≤5 months, and <5 to ≤6 age groups (*P* = .012, *P* = .041, and *P* < .001, respectively) (Table 2).

The grouping of the newborns and infants as 0 to 3 months and 4 to 6 months revealed significant differences in the AI and ADR-B values between the left and right hips for both genders (*P* < .05). The left AI values of the male, and female newborns and infants were significantly higher than those of the right hip in both 0 to 3 months and 4 to 6 months age groups (*P* < .001 for all). Similarly, the left ADR-B values of male and female newborns and infants were significantly lower than those of the right hip in both 0 to 3 months and 4 to 6 months age groups (*P* < .05). On the other hand, there was no significant difference between the age groups in ADR-A values regardless of gender (Table 3).

Table 1

The values of acetabular index, acetabular depth ratio A and acetabular depth ratio B of the left and right sided measurements.

	Overall (n = 1132)
AI °	
Left hip	25.400 ± 3.492
Right hip	24.417 ± 3.257
ADR-A	
Left hip	0.211 ± 0.036
Right hip	0.209 ± 0.036
ADR-B	
Left hip	0.156 ± 0.031
Right hip	0.160 ± 0.031

ADR-A = acetabular depth ratio A, ADR-B = acetabular depth ratio B, AI = acetabular index.

There were fair to moderate correlations between age and the left and right hips' AI, ADR-A, and ADR-B values. The AI values had fair negative correlations, whereas the ADR-A and ADR-B values had moderate positive correlations with age. The Spearman correlation coefficients of the correlations between age and AIs of left and right hips were −0.286 and −0.254 (*P* < .001 for both cases). The ADR-A and ADR-B values had higher positive correlation coefficient values with age than AI for both sides (Table 4). In sum, as the age of the infants increased, the AI values decreased, whereas the ADR values increased.

There was no significant difference between the degrees of correlation of these parameters with age in terms of gender (Table 4). Significant correlations between AI, ADR-A, and ADR-B values of the left and right hips were detected (Table 5).

The ICC values pertaining to 2 different measurement periods (inter-observer reliability) were between 0.845 and 0.989 (excellent) for AI, 0.534 and 0.904 (moderate to excellent) for ADR-A, and −0.014 and 0.774 (slight to good) for ADR-B (Table 6).

The ICC values pertaining to 2 different measurement periods (intra-observer reliability) were 0.915 to 0.989 (excellent) on the left side and 0.811 to 0.996 (excellent) on the right side for AI, between 0.575 and 0.987 (moderate to good) on the left side and 0.643 to 0.960 (good to excellent) on the right side, for ADR-A, and between 0.840 and 0.938 (excellent) on the left side and 0.023 to 0.954 (slight to excellent) on the right side for ADR-B (Table 7).

4. Discussion

This study featured the measurements of AI and ADR performed using the radiographs of healthy newborns and infants aged 0 to 6 months. Normative AI and ADR data are critical

Table 2

Comparison of the age-based acetabular index, acetabular depth ratio A and acetabular depth ratio B measurements between the left and right hips in male and female newborns and infants.

		Male (n = 635)			Female (n = 497)		
Age-based groups*	n	Left	Right	*P*	Left	Right	*P*
AI °							
≤1 mo	222	26.564 ± 3.557	25.23 ± 3.335	**<.001**	27.196 ± 3.097	26.143 ± 3.125	**<.001**
<1–≤2 mo	282	25.069 ± 3.414	23.929 ± 2.773	**<.001**	27.35 ± 3.556	26.126 ± 3.314	**<.001**
<2–≤3 mo	200	24.677 ± 3.05	23.711 ± 2.877	**<.001**	26.303 ± 2.828	25.501 ± 3.04	**.003**
<3–≤4 mo	146	23.971 ± 3.393	23.083 ± 2.727	**<.001**	25.194 ± 3.037	24.398 ± 2.932	**.008**
<4–≤5 mo	119	23.494 ± 3.3	23.019 ± 3.445	.070	25.398 ± 2.616	24.917 ± 2.801	.122
<5–≤6 mo	163	22.945 ± 2.852	22.144 ± 2.757	**<.001**	25.036 ± 3.468	23.943 ± 3.218	**<.001**
ADR-A							
≤1 mo	222	0.184 ± 0.034	0.186 ± 0.034	.446	0.188 ± 0.029	0.18 ± 0.034	**.024**
<1–≤2 mo	282	0.206 ± 0.032	0.202 ± 0.033	.201	0.201 ± 0.033	0.196 ± 0.031	.072
<2–≤3 mo	200	0.218 ± 0.03	0.215 ± 0.029	.221	0.205 ± 0.031	0.209 ± 0.034	.246
<3–≤4 mo	146	0.227 ± 0.033	0.229 ± 0.033	.523	0.217 ± 0.031	0.218 ± 0.031	.666
<4–≤5 mo	119	0.233 ± 0.034	0.229 ± 0.035	.433	0.222 ± 0.026	0.22 ± 0.027	.613
<5–≤6 mo	163	0.236 ± 0.036	0.236 ± 0.03	.883	0.227 ± 0.033	0.225 ± 0.032	.645
ADR-B							
≤1 mo	222	0.129 ± 0.027	0.133 ± 0.025	.078	0.131 ± 0.028	0.133 ± 0.028	.289
<1–≤2 mo	282	0.15 ± 0.024	0.153 ± 0.023	.116	0.145 ± 0.027	0.151 ± 0.028	**.012**
<2–≤3 mo	200	0.155 ± 0.028	0.161 ± 0.025	**.021**	0.158 ± 0.024	0.163 ± 0.029	**.041**
<3–≤4 mo	146	0.17 ± 0.028	0.172 ± 0.028	.408	0.169 ± 0.026	0.17 ± 0.02	.657
<4–≤5 mo	119	0.175 ± 0.026	0.179 ± 0.024	.156	0.174 ± 0.024	0.181 ± 0.026	**.024**
<5–≤6 mo	163	0.18 ± 0.025	0.188 ± 0.027	**.007**	0.175 ± 0.025	0.187 ± 0.024	**<.001**

Paired samples t test. *P* values in bold represent significance <0.05.

*The age-based groups represent subjects below 1 mo of age, ≤1 mo; below 2 mo but above 1 mo of age, <1–≤2 mo; below 3 mo but above 2 mo of age, <2–≤3 mo; below 4 mo but above 3 mo of age, <3–≤4 mo; below 5 mo but above 4 mo of age, <4–≤5 mo and below 6 mo but above 5 mo of age, <5–≤6 mo.

ADR-A = acetabular depth ratio A, ADR-B = acetabular depth ratio B, AI = acetabular index.

as reference values in the pelvic roentgenographic imaging used to screen developmental hip dysplasia. This is the first study to date that addressed the AI and ADR data pertaining to newborns (<1 month) in Turkey. Another finding of this study, that is, the strong correlation between ADR-B and AI, might lead to the use of the pubic bone as a landmark for the measurements of ADR.

Several universally accepted parameters, including AI and ADR, are used in diagnosing congenital hip dysplasia.[1] Radiography has been used in the diagnosis of congenital hip dysplasia. Then again, several authors investigated the efficiency of USG and magnetic resonance imaging for the metric evaluations of the pelvis.[2,4–6,23] This study utilized only the metric values of the radiographic parameters, such as AI and ADR.

It is possible to make a standardized evaluation of pelvic anatomy with reliable reference values.[17,18] Novais et al[1] constructed standard percentile curves of AI and ADR for infants and children aged from 0.15 to 13.97 years. Nevertheless, these studies included infants with DDH due to the unavailability of ultrasonographic screening at the time.

There are several studies performed in Turkey focusing on the roentgenographic evaluation of the hips. In one of these studies, Akel et al[15] analyzed the AI values in healthy Turkish infants and children aged between 6 months and 8 years and categorized them into 3 groups based on the SD above the mean as normal, mild, and severe dysplasia groups, and found a negative correlation between AI and age. The AI values of children aged between 5 and 11 years in Turkey were investigated in another study.[21] In another study, Akpinar et al[22] studied the hip roentgenograms of healthy children aged 1 to 12 months and found an inverse relationship between AI and age and higher values of AI in females than in males. In comparison, this study featured infants aged up to 6 months.

Previous studies reported higher AI values in the female pelvis, with controversial results related to the sides of the hip addressed in these measurements.[1,15,17,18,21,24] In comparison, the AI values of females were also higher than those of males in this study. Additionally, the AI values of the left hips were higher than the right hips. It is challenging to explain the differences in the AI values between genders and different sides of the hip, regardless of age.[24,25]

The reliability of AI and ADR measurements is another matter subject to debate. Previous studies reported good to excellent agreement results.[1,3,19–21] Similarly, excellent agreement results were obtained in this study for the intra- and inter-observer reliability of AI measurements.

The normative ADR data and the correlation between AI and ADR in children have not been addressed in previous studies.[1] One of the studies on the subject was conducted by Park et al[26] in an adult patient group, in which an inverse correlation (r = −0.378) was found between AI and the acetabular depth, which was used instead of ADR. In contrast, as in this study, Novais et al[1] used the ADR values and found a high coefficient value (r = −0.789) between AI and ADR for all included hips, and relatively higher coefficient values in female patients and left-sided measurements. In comparison, in this study, ADR was measured from 2 different anatomic points, the ischium (ADR-A) and the pubic bone (ADR-B).[19] As a novel approach, the use of pubic bone as the landmark for the measurements of ADR, as done in this study, might lead to obtaining more accurate results. The ossification level of the pubic bone might be more evident than that of the ischium. The relatively higher correlations between AI and

Table 3

Comparison of the age grouping-based acetabular index, acetabular depth ratio A and acetabular depth ratio B measurements between the left and right hips in male and female newborns and infants.

		Male (n = 635)			Female (n = 497)		
Age-Based Groups*		**Left**	**Right**	***P***	**Left**	**Right**	***P***
AI °							
0–3 mo	n = 704	25.439 ± 3.449	24.284 ± 3.053	**<.001**	26.986 ± 3.23	25.943 ± 3.178	**<.001**
4–6 mo	n = 428	23.455 ± 3.191	22.718 ± 2.981	**<.001**	25.186 ± 3.102	24.357 ± 3.025	**<.001**
ADR-A							
0–3 mo	n = 704	0.202 ± 0.035	0.201 ± 0.034	.272	0.198 ± 0.032	0.195 ± 0.035	.091
4–6 mo	n = 428	0.232 ± 0.035	0.232 ± 0.032	.814	0.222 ± 0.031	0.222 ± 0.03	.784
ADR-B							
0–3 mo	n = 704	0.145 ± 0.028	0.149 ± 0.027	**.001**	0.144 ± 0.028	0.149 ± 0.031	**.001**
4–6 mo	n = 428	0.175 ± 0.026	0.18 ± 0.027	**.004**	0.172 ± 0.025	0.18 ± 0.024	**<.001**

Paired samples t test. *P* values in bold represent significance <0.01.

*The age-based groups represent subjects below 3 mo of age, 0–3 mo and below 6 mo but above 3 mo of age, 3–6 mo.

ADR-A = acetabular depth ratio A, ADR-B = acetabular depth ratio B, AI = acetabular index.

Table 4

Correlation of the left and right sided acetabular index, acetabular depth ratio A and acetabular depth ratio B values with age in the overall, male and female newborn and infant groups.

		Overall		Male		Female	
Side	Parameter	r	*P*	r	*P*	r	*P*
Left	AI	−0.286	**<.001**	−0.329	**<.001**	−0.265	**<.001**
	ADR-A	0.449	**<.001**	0.476	**<.001**	0.422	**<.001**
	ADR-B	0.545	**<.001**	0.554	**<.001**	0.532	**<.001**
Right	AI	−0.254	**<.001**	−0.295	**<.001**	−0.239	**<.001**
	ADR-A	0.469	**<.001**	0.492	**<.001**	0.450	**<.001**
	ADR-B	0.592	**<.001**	0.599	**<.001**	0.580	**<.001**

P values written bold represent significance <.001.

ADR-A = acetabular depth ratio A, ADR-B = acetabular depth ratio B, AI = acetabular index, r = spearman rho correlation coefficient.

Table 5

Correlation of the left and right sided acetabular index with the left- and -right sided acetabular depth ratio A and acetabular depth ratio B in the overall, male and female newborn and infant groups.

			Overall		Male		Female	
			r	*P*	r	*P*	r	*P*
Left								
AI	–	ADR-A	–0.604	**<.001**	–0.612	**<.001**	–0.591	**<.001**
AI	–	ADR-B	–0.520	**<.001**	–0.546	**<.001**	–0.512	**<.001**
ADR-A	–	ADR-B	0.626	**<.001**	0.639	**<.001**	0.612	**<.001**
Right								
AI	–	ADR-A	–0.592	**<.001**	–0.608	**<.001**	–0.568	**<.001**
AI	–	ADR-B	–0.488	**<.001**	–0.538	**<.001**	–0.469	**<.001**
ADR-A	–	ADR-B	0.660	**<.001**	0.673	**<.001**	0.653	**<.001**

P values written bold represent significance <.001.

ADR-A = acetabular depth ratio A, ADR-B = acetabular depth ratio B, AI = acetabular index, r = pearson rho correlation coefficient.

Table 6

Intraclass correlation coefficient analysis of the inter-observer reliability.

Left		ICC	95% CI	*P* value
Time period 1	AI	0.914	0.876–0.943	**<.001**
	ADR-A	0.904	0.862–0.936	**<.001**
	ADR-B	0.762	0.671–0.835	**<.001**
Time period 2	AI	0.862	0.804–0.907	**<.001**
	ADR-A	0.597	0.469–0.709	**<.001**
	ADR-B	0.644	0.526–0.747	**<.001**
Right				
Time period 1	AI	0.989	0.983–0.992	**<.001**
	ADR-A	0.702	0.596–0.791	**<.001**
	ADR-B	0.774	0.687–0.844	**<.001**
Time period 2	AI	0.845	0.780–0.895	**<.001**
	ADR-A	0.534	0.398–0.659	**<.001**
	ADR-B	–0.014	–0.134 to 0.135	.568

P values written bold represent significance <.001.

ADR-A = acetabular depth ratio A, ADR-B = acetabular depth ratio B, AI = acetabular index, CI = confidence interval, ICC = intraclass correlation coefficient.

Table 7

Intraclass correlation coefficient analysis of the intra-observer reliability.

	Observer 1			Observer 2			Observer 3		
Left	ICC	95% CI	*P* value	ICC	95% CI	*P* value	ICC	95% CI	*P* value
AI	0.915	0.866–0.946	**<.001**	0.996	0.994–0.998	**<.001**	0.989	0.982–0.993	**<.001**
ADR-A	0.575	0.394–0.713	**<.001**	0.978	0.964–0.986	**<.001**	0.957	0.931–0.973	**<.001**
ADR-B	0.84	0.755–0.898	**<.001**	0.938	0.902–0.961	**<.001**	0.854	0.775–0.907	**<.001**
Right									
AI	0.811	0.712–0.878	**<.001**	0.996	0.994–0.998	**<.001**	0.975	0.960–0.984	**<.001**
ADR-A	0.643	0.482–0.762	**<.001**	0.960	0.936–0.975	**<.001**	0.957	0.932–0.973	**<.001**
ADR-B	0.747	0.622–0.835	**<.001**	0.954	0.928–0.971	**<.001**	0.023	–0.212 to 0.255	.425

P values written bold represent significance <.001.

ADR-A = acetabular depth ratio A, ADR-B = acetabular depth ratio B, AI = acetabular index, CI = confidence interval, ICC = intraclass correlation coefficient.

ADR-B suggest using the pubic bone as the landmark for ADR measurements.

The primary strength of this study was the inclusion of newborns and infants with rapid skeletal changes, whereas its secondary strength was the homogenous distribution of all age groups in the study group. On the other hand, there were some limitations to this study. The absence of a standardized positioning and the retrospective analysis of all radiographs, including anterior-posterior pelvic, hip, lumber, or abdomen radiographs, might have negatively impacted the measurements. Extreme deviations in pelvic positioning might have led to pelvic tilt and rotation. Also, wide range of both the ADR-A and ADR-B measurements according to the age of the newborns and infants should be taken as a limitation.

5. Conclusion

This study features the first complete AI and ADR data set in newborns and infants aged ≤6 months, which can be used as the baseline normative data for screening hip dysplasia using pelvic radiographs. In addition, the study findings suggest that the pubic bone may be used as the landmark for ADR measurements.

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