Original Article

Med J Bakirkoy 2021;17(1):41-7
doi: 10.5222/BMJ.2021.85547

Medical Journal of Bakirkoy

The Comparison Between Forensic Staging System and Risser Classification for Iliac Crest Apophysis

İliyak Krest Apofizi için Adli Evreleme Sistemi ile Risser Sınıflandırmasının Karşılaştırması

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Received: 17.12.2020 / **Accepted:** 26.01.2021 / **Published Online:** 31.03.2021

Cite as: Basa CD, Kacmaz IE. The comparison between forensic staging system and Risser classification for iliac crest apophysis. Med J Bakirkoy 2021;17(1):41-7.

ABSTRACT

Objective: *In this study evaluation of the ossification of iliac crest apophysis with widely used forensic staging system in idiopathic scoliosis patients.*
Method: *Radiographs of 98 scoliosis patients (76 females, 22 males; age range: 5–24 years) were examined and 196 iliac crest apophyses were evaluated using forensic staging system.*
Results: *The forensic staging system has four stages, and 6 substages (1,2a-c, 3a-c and 4). Of 196 iliac crests evaluated, 65 were stage 2 (Risser stage 4–5) and 6 were stage 3 (Risser stage 5).*
Conclusion: *The forensic staging system for the ossification of the iliac crest apophysis provided more detailed clinical follow-up data. Studies with larger series may help to improve the forensic staging system.*

Keywords: *classification, orthopedics, pelvis, scoliosis*

ÖZ

Amaç: *Bu çalışmada, idiyopatik skolyoz hastalarında yaygın olarak kullanılan iliyak krest apofiz ossifikasyonunun adli evreleme sistemiyle değerlendirilmesi amaçlanmıştır.*
Yöntem: *98 skolyoz hastasının (76 kadın, 22 erkek; yaş aralığı: 5-24 yaş) radyografileri incelendi ve 196 iliak krest apofizi adli evreleme sistemine göre değerlendirildi.*
Bulgular: *Adli evreleme sisteminde dört evre ve altı alt evre vardır (1,2a-c,3a-c ve 4). Değerlendirilen 196 iliak kanat grafisinden 65'inin evre 2 (Risser evre 4-5) ve 6'sının evre 3 (Risser evre 5) olduğu saptandı.*
Sonuç: *İliyak krest apofizi için adli evreleme sistemi, daha ayrıntılı klinik takip verileri sağlamıştır. Daha geniş serilerle yapılan çalışmalar, adli evreleme sistemini iyileştirmeye yardımcı olabilir.*

Anahtar kelimeler: *sınıflandırma, ortopedi, pelvis, skolyoz*

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INTRODUCTION

Adolescent idiopathic scoliosis (AIS) is a rotational deformity that develops in the vertebral column without congenital or neurological anomalies. Vertebral curvature exceeding 10° is observed in 2% of adolescents [1]. The treatment of AIS is based on the degree of curvature (i.e., the Cobb angle) and skeletal maturity, as determined by various radiological methods including the degree of epiphyseal closure on wrist radiographs and the Risser stage based on the degree of ossification of the iliac apophysis. The Tanner stage and menarche age can also be used to determine skeletal maturity [2].

In 1958, Risser reported that spinal skeletal maturity in AIS was associated with ossification of the iliac apophysis [3]. Risser et al. emphasized the high correlation between ossification of the iliac apophysis and the development of vertebral growth plates as an important parameter [3]. Clinicians have used the Risser staging system, including modified versions, when following idiopathic scoliosis patients [3-5]. The original Risser staging system was modified by French researchers. Both systems are currently used by clinicians [6].

Determination of skeletal maturity is informative for clinicians regarding the progression of AIS deformity. Accurate prediction of AIS progression also facilitates treatment planning, which may include physical therapy, functional bracing, and surgery. The Cobb angle plays a decisive role in treatment planning. Follow-up is recommended in cases with a Cobb angle of 10–19°, follow-up or a functional brace in those with angles of 20–29°, a functional brace in those with angles of 29–40°, and surgical treatment when the angle exceeds 40°. Risser stage 4 patients with angles of 20–29° can just be followed, while in Risser stage 4 cases with angles exceeding 40°, surgery can be delayed [7-11].

In the Risser staging system, the ossification of the iliac apophysis is assigned to one of six stages (from 0 to 5). Currently, different systems are used in the USA and France [3,4,6]. While the US system considers iliac crest ossifications starting anterolaterally or posteromedially as stage 4, the modified French system divides ossification into three subgroups [4-6,12].
Ossification of the iliac crest apophysis has been also used for a long time by forensic experts and anthropologists, who use different staging methods, to determine the age of a person based on direct analysis or X-ray evaluation [13,14]. Iliac crest apophysis has been evaluated with X-rays [15-17], ultrasonography (USG) [18-19], magnetic resonance imaging (MRI) [18], and computed tomography (CT) [20] to determine the age, and thus the legal and civil responsibilities, of living individuals, and to verify that athletes have the appropriate licenses.

At present, no research has evaluated iliac crest development using a forensic staging system of the AIS. Thus, presented study aims to explore the utility of forensic staging system for the AIS patients and whether substages of forensic system are advantageous compared with the Risser staging system.

MATERIALS AND METHODS

The spine X-rays of 98 scoliosis patients (76 females, 22 males) diagnosed with AIS at a training and research hospital were evaluated retrospectively. The study enrolled all individuals with anteroposterior (AP) spinal X-rays showing all bone structures from the occipital bone to the femoral head. The local ethics board approved the study protocol.

All X-ray examinations were performed using the same digital radiography system (XGEO-GC80; Samsung, Seoul, Korea). Radiological monitors (RadiForce RX350; EIZO, Tokyo, Japan) with a resolution of 2.048 × 1.536 pixels were used to interpret the images.

All cases were evaluated individually using both staging systems by two orthopedic surgeons (R1 and R2), who subsequently reassessed all cases while blinded to the initial assessment and age information to determine the intraobserver reliability. In all evaluations, the examiners were blinded to age and sex information. Both specialists were trained by an experienced forensic medicine and anthropology specialist for forensic staging system. Cohen's nonparametric kappa (κ) was used to measure the intra- and interobserver reliability.

Wittschieber et al. reported a method to determine the degree of ossification of the iliac apophysis, based on a modification of the methods of Kreitner et al. and Kellinghaus et al. [16,21,22]. The grading is as follows:

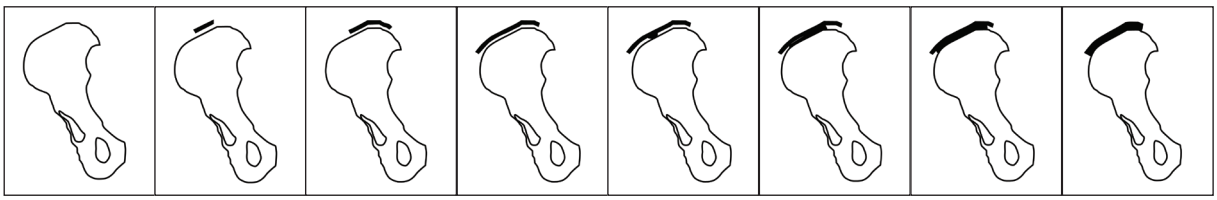

Figure 1A **Figure 1B** **Figure 1C** **Figure 1D** **Figure 1E** **Figure 1F** **Figure 1G** **Figure 1H**

Stage 1: Ossification center is not fully ossified (**Figure 1A**)
Stage 2: The areas of ossification of the apophyseal cartilage and iliac wing are compared:
Stage 2a: The former is one third or less than the latter (**Figure 1B**)
Stage 2b: The former is over one third, and less than two thirds of the latter **(Figure 1C)**
Stage 2c: The former is over two thirds of the latter (**Figure 1D**)
Stage 3: The degree of apophyseal fusion to the iliac bone is assessed:
Stage 3a: Fusion is one third or less than complete fusion (**Figure 1E**)
Stage 3b: Fusion is over one third, and less than two thirds of complete fusion (**Figure 1F**)
Stage 3c: Fusion is over two thirds of complete fusion (**Figure 1G**)
Stage 4: The apophyseal cartilage is fully ossified (**Figure 1H**)

The Risser system used in the USA is a six-stage system, in which the iliac crest apophysis is divided into quarters:
Stage 0: No ossification
Stage 1: Apophyseal ossification within the first quarter (< 25%), starting anterolaterally
Stage 2: Apophyseal ossification extending into the second quarter (25–50%)
Stage 3: Apophyseal ossification extending into the third quarter (50–75%)
Stage 4: Apophyseal ossification extending into the fourth quarter (≥ 75–100%)
Stage 5: Complete fusion of the iliac crest apophysis, starting posteromedially.

STATISTICAL METHODS

SPSS software (ver. 22.0; IBM Corp., Armonk, NY, USA) was used to analyze the data. The normality of the data distribution was evaluated by the Shapiro–Wilk test and homogeneity of variance was evaluated by the Levene test. The independent-samples *t*-test (with bootstrapping) was used to compare quantitative data between two independent groups. The compatibility of the forensic and Risser staging systems was evaluated using Kendall's tau-c and Cohen's kappa. The Wilcoxon test was used to evaluate the differences between the ossification stages of the right and left iliac crest for both staging systems. In the tables, quantitative variables are shown as mean ± standard deviation (SD), median ± interquartile range (IQR) or median (range), and categorical variables as n (%). *P*-values < 0.05 were considered significant.

Correlations between the Risser and forensic staging system classifications of 0.10–0.29, 0.30–0.49, and 0.50–1.00 were categorized as low, intermediate, and high, respectively. Cohen's nonparametric κ was used to examine the intra- and interobserver reliability, with κ values < 0, 0.0–0.20, 0.21–0.40, 0.41–0.60, 0.61–0.80, and 0.81–1.00 indicating poor, slight, fair, moderate, substantial, and almost perfect agreement, respectively.

RESULTS

We enrolled 98 patients (76 females, 22 males) diagnosed with AIS in this study. The mean age was 13.58 ± 3.33 years (range: 5–24 years) (**Table 1**). The correlation between the Risser and forensic system classifications was high (0.50–1.00) and the κ value corresponded to the almost perfect classification (0.81-1.00) (**Tables 2 and 3**). Correlation analysis between the forensic and Risser staging system classifications was also performed after combining stages 3a, 3b, and 3c. There was perfect agreement between the classification systems, for both females, males, and the entire cohort (all $p < 0.001$) (**Tables 2 and 3**). The intraobserver agreement for the iliac crest apophysis was κ =0.924, and the interobserver reliability was κ =0.898. Thus, intra- and interobserver evaluation showed very good repeatability and consistency of the method for both the Risser and forensic staging system.

Table 1. Gender distribution of the cases.

		Age		
	N	Mean±SD	Maximum	Minimum
Female	76	13.36±3.20	20	5
Male	22	14.36±3.72	24	5
Total	98	13.58±3.33	24	5

Independent T test (Bootstrap) SD.:Standard Deviation

Table 2. Distribution of Ossification Stages of The Iliac Crest according to Risser And Forensic Staging System and Correlation Results with Correlation Coefficients and Kappa Values According to Laterality of the Ossification.

		Risser Staging							r / P K / P
		0	**1**	**2**	**3**	**4**	**5**	**Total**	
	Forensic Staging	**n**	**n**	**n**	**n**	**n**	**n**	**n**	
Left Total	**1**	25	0	0	0	0	0	25	**0,853 / <0,001** **0,823 / <0,001**
	2a	4	9	1	0	0	0	14	
	2b	0	0	4	2	0	0	6	
	2c	0	0	0	2	2	0	4	
	3a	0	0	0	1	13	1	15	
	3b	0	0	0	0	10	0	10	
	3c	0	0	0	0	11	2	13	
	4	0	0	0	0	0	11	11	
	Total	**29**	**9**	**5**	**5**	**36**	**14**	**98**	
Right Total	**1**	30	0	0	0	0	0	30	**0,870 / <0,001** **0,864 / <0,001**
	2a	0	8	1	1	0	0	10	
	2b	0	0	3	1	0	0	4	
	2c	0	0	0	4	1	0	5	
	3a	0	0	0	2	9	1	12	
	3b	0	0	0	1	9	0	10	
	3c	0	0	0	0	13	2	15	
	4	0	0	0	0	0	12	12	
	Total	**30**	**8**	**4**	**9**	**32**	**15**	**98**	
Total	**1**	55	0	0	0	0	0	55	**0,808 / <0,001** **0,843 / <0,001**
	2a	4	17	2	1	0	0	24	
	2b	0	0	7	3	0	0	10	
	2c	0	0	0	6	3	0	9	
	3a	0	0	0	3	22	2	27	
	3b	0	0	0	1	19	0	20	
	3c	0	0	0	0	24	4	28	
	4	0	0	0	0	0	23	23	
	Total	**59**	**17**	**9**	**14**	**68**	**29**	**196**	

Kendall's tau-c Test r :Correlation Coefficient, Cohen's kappa Statistic (K)

Evaluation of the differencies of iliac crest ossification showed that 20 patients for forensic system and 10 patients for Risser system are different. Maximum grade differencies are only one stage for both staging system. No significant differences between the ossification stages of the right and left iliac crests were observed for both staging system.

DISCUSSION

Ossification of the iliac crest apophysis is a useful guide for the determination of forensic age. Different staging systems and methods are being used for forensic age determination, based on direct bone and radiological examinations of the iliac crest [13,14], including X-rays [15-17], CT [20], USG [19] and MRI [18]. Wittschieber et al. combined the four-stage system of Kreitner et al. with the lower stages of Kellinghaus et al. in an X-ray study [16,21,22]. Schmidt et al. used a four-stage system for ultrasonographic assessment of the iliac crest [19]. Wittschieber et al. used the four-stage system of Webb et al. in an MRI study of football players. In a CT study, Ekizoglu et al. also applied a four-stage system [13,18,20]. In clinical practice, the Risser staging system is used most commonly to determine skeletal maturation according to the degree of closure of the iliac apophysis.

We found a high correlation between the classifications of the US version of the Risser staging system, which is easy to apply clinically, and our forensic staging system. Detailed staging based on ossification enables more accurate determination of age; for example, clavicle ossification indicates an age of 19 years. Previously, stage 3 of the system of Kreitner et al. was considered to indicate first stage of epiphyseal closure, but this stage was later subdivided by Kellinghaus et al. [22]. Detailed assessment of the degree of closure may contribute to the surgical decision- making process. We believe that our forensic staging system provides a more detailed analysis than the Risser staging system, especially since stage 3, which corresponds to Risser stage 4–5, is divided into three substages (a–c). Here, we determined the stage 3 substages corresponding to Risser stage 4–5 for the left and right iliac wings in 34 and 31 cases, respectively (33% of all cases).

Risser stage 4, which is considered the stage in which progression of AIS ceases, is the most important stage in terms of informing treatment decisions. However, some studies showed that AIS progression can continue into stage 5 [23]. Histologically, Little et al. showed that growth of the vertebral endplate continued through Risser stage 4 before ending in stage 5 [11]. We identified 22, 19, and 24 cases in stages 3a, b, and c, respectively (i.e., Risser stage 4–5). There may be subtle differences between stages that affect the clinical follow-up.

In adolescent males, curvature may progress into Risser stage 5 with the onset of late scoliosis [24]. In our series, 29 cases were of Risser stage 5 and 23 were stage 4; 6 of the latter belonged to one of our stage 3 subgroups and apophyseal closure was incomplete, although according to the Risser staging system closure should be complete at stage 4.

This study had some limitations. First, we did not have any data on the socioeconomic status of our study population; the association of socioeconomic status with skeletal maturity should be considered in future [25,26]. In addition, forensic staging is strongly influenced by the observer's experience, as in all clinical and radiological staging studies. Although the intra- and interobserver reliability were very high for the forensic and Risser staging systems, in clinical practice, especially in stage 3 substages, the results may be affected by observer experience [27].

Due to the S-shape of the iliac crest, the actual ossification status, especially whether the closure involves the entire iliac crest, is difficult to determine radiographically, and the use of CT and MRI did not allow for substage classification. This problem could be overcome by three-dimensional (3D) iliac crest analysis. The CT evaluation of the pelvis gave results compatible with those of X-ray, but has the disadvantage of high radiation exposure. In addition, CT examination is not feasible for staging and age determination because of its high cost and requirement for observer experience.

In conclusion, our forensic staging system, based on X-ray assessment of the iliac crest, provided results consistent with those of the Risser staging system, and had the advantage of dividing Risser stage 4–5 into three substages. Its utility is supported by the good intra- and interobserver reliability. In future, CT could improve the accuracy of the system as a supporting method using thin sections and three-dimensional reconstruction.

Table 3. Distribution of Ossification Stages of The Iliac Crest with Risser and Forensic Staging System and Correlation Results with Correlation Coefficients and Kappa Values According to Sex.

		Forensic Staging	Risser Staging					
			0	1	2	3	4	5
			n	n	n	n	n	n
Female	Left	1	17	0	0	0	0	0
		2a	3	9	1	0	0	0
		2b	0	0	4	1	0	0
		2c	0	0	0	2	1	0
		3a	0	0	0	1	10	0
		3b	0	0	0	0	9	0
		3c	0	0	0	0	10	2
		4	0	0	0	0	0	6
		Total	**20**	**9**	**5**	**4**	**30**	**8**
	Right	1	21	0	0	0	0	0
		2a	0	8	0	1	0	0
		2b	0	0	3	1	0	0
		2c	0	0	0	4	0	0
		3a	0	0	0	2	9	0
		3b	0	0	0	1	5	0
		3c	0	0	0	0	12	2
		4	0	0	0	0	0	7
		Total	**21**	**8**	**3**	**9**	**26**	**9**
	Total	1	38	0	0	0	0	0
		2a	3	17	1	1	0	0
		2b	0	0	7	2	0	0
		2c	0	0	0	6	1	0
		3a	0	0	0	3	19	0
		3b	0	0	0	1	14	0
		3c	0	0	0	0	22	4
		4	0	0	0	0	0	13
		Total	**41**	**17**	**8**	**13**	**56**	**17**
Male	**Left**	1	8	0	0	0	0	0
		2a	1	0	0	0	0	0
		2b	0	0	0	1	0	0
		2c	0	0	0	0	1	0
		3a	0	0	0	0	3	1
		3b	0	0	0	0	1	0
		3c	0	0	0	0	1	0
		4	0	0	0	0	0	5
		Total	**9**	**0**	**0**	**1**	**6**	**6**
	Right	1	9	0	0	0	0	0
		2a	0	0	1	0	0	0
		2b	0	0	0	0	0	0
		2c	0	0	0	0	1	0
		3a	0	0	0	0	0	1
		3b	0	0	0	0	4	0
		3c	0	0	0	0	1	0
		4	0	0	0	0	0	5
		Total	**9**	**0**	**1**	**0**	**6**	**6**
	Total	1	17	0	0	0	0	0
		2a	1	0	1	0	0	0
		2b	0	0	0	1	0	0
		2c	0	0	0	0	2	0
		3a	0	0	0	0	3	2
		3b	0	0	0	0	5	0
		3c	0	0	0	0	2	0
		4	0	0	0	0	0	10
		Total	**18**	**0**	**1**	**1**	**12**	**12**

Ethics Committee Approval: S.B.Ü. Tepecik Training and Research Hospital Clinical Research Ethics Committee (2020/13-20, 16.11.2020).
Conflict of Interest: No conflict of interest was declared by the authors.
Funding: No funding was recieved.
Informed Consent: Informed consent was not obtained since the study is retrospective.

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