Clinical Research

Observer Variability of Pediatric Bone Age Assessment by Using The Greulich and Pyle Method

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ABSTRACT

Objective: Determination of skeletal maturity has an important role for diagnosis and management of pediatric growth disorders. We aimed to determine the effects of knowing chronological age on intra / interobserver variability of pediatric bone age determination by using the Greulich and Pyle method.
Material and Method: The study group consisted of 115 boys, ages ranging from 3-198 months and 113 girls, ages ranging from 2-186 months. Plain left hand radiographs were obtained from children who came to pediatric outpatient department during 1 year. Patients' hand radiographs were evaluated by using Greulich and Pyle atlas by radiologists who were blinded to chronological ages. Radiographs were reevaluated with knowledge of chronological ages one month later. Three radiologists interpreted plain radiographs for determination of interobserver variability. Radiographs of 23 boys and 27 girls were reevaluated two months later with and without knowledge of chronological ages for determination of intraobserver variability.
Results: Although it was not statistically significant ($p>0.05$) , all the observers are more likely to interpret the radiograph as showing normal findings when chronological age is known than if the interpretation is performed with the observer unaware of chronological age. When chronological age was known and when the age was not known, in both basal and second interpretations, determination of bone age was consistent with chronological age for each observer ($p<0.001$).
Conclusion: Knowledge of chronological age prior to the assessment of radiographs does not affect reliability.

Key Words: *Bone age, Greulich and Pyle, Pediatric.*

ÖZET

Greulich and Pyle Atlası Kullanılarak Yapılan Çocuklardaki Kemik Yaşı Değerlendirmesinde Değerlendirici Değişkenliği

Amaç: Çocuklardaki büyüme bozukluklarının tanı ve takibinde iskelet matüritesinin değerlendirilmesi önemlidir. Greulich and Pyle atlasını kullanarak çocuklardaki kemik yaşının belirlenmesinde, kronolojik yaşı bilmenin, değerlendiricilerin birbiriyle ve kendi içerisindeki etkisini araştırdık.
Gereç ve Yöntem: Yaşları 3-198 ay arasında değişen, 115 erkek çocuk ile yaşları 2-186 ay arasında değişen, 113 kız çocuğu çalışma grubunu oluşturdu. Bir yıllık sürede çocuk polikliniğine gelen olguların sol el-bilek grafisi elde edildi. Kronolojik yaşlarını bilmeden ve yaklaşık 1 ay sonra kronolojik yaşlarını bilerek, el-bilek grafileri Greulich ve Pyle atlası temel alınarak değerlendirildi. Değerlendiriciler arasındaki farklılığı saptamak için grafiler 3 radyolog tarafından değerlendirildi. Değerlendiricilerin kendi içlerindeki farklılığı belirlemek için 23 erkek ve 27 kız olgunun grafileri yaklaşık iki ay sonra ikinci kez olguların kronolojik yaşlarını bilmeden ve kronolojik yaşlarını bilerek değerlendirildi.
Bulgular: 3 değerlendiricinin her biri için, kronolojik yaşlarını bilerek değerlendirmede, kronolojik yaşlarını bilmeden değerlendirmeye göre normal bilme değerlerinde artış olmakla birlikte istatistiksel olarak anlamlı değildi ($p>0.05$). Değerlendiriciler arasında anlamlı fark saptanmadı. Bazal ve ikinci kez değerlendirmede, olguların kronolojik yaşını bilmeden ve bilerek değerlendirmenin her ikisinde de, değerlendiricilerin saptadığı kemik yaşı ile kronolojik yaş değerleri uyumluydu ($p<0.001$).
Sonuç: Radyografileri değerlendirmeden önce kronolojik yaşın bilinmesi güvenilirliği etkilememektedir.

Anahtar Kelimeler: *Kemik yaşı, Greulich and Pyle, Çocuk.*

The assessment of skeletal maturity is an important part of the diagnosis and management of pediatric growth disorders. Reliable and accurate determination of skeletal age is important for several reasons. The estimation of adult height can be determined from bone age radiographs for a child with a growth abnormality. In children for whom hormonal therapy is being considered, time of initiation and duration of therapy rely on accurate assessment of skeletal age. Additionally, many orthopedic interventions, including

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the management of limb-length discrepancies and scoliosis, rely on accurate bone age determination for optimal timing (1). In addition to physicians, lawyers may also have an interest in skeletal age assessment. When representing young criminals or refugees seeking asylum it can be important to know if the person they represent is younger or older than 18 years of age (2, 3).

The methods most widely used for bone age determination are those of Tanner and Whitehouse (4) and Greulich and Pyle (5). Some studies have compared these two methods and found minor but not significant differences between them (6-8). However, the Greulich and Pyle method appeared to be less time-consuming and tedious and is therefore preferred in many institutions. Both methods are at least partially subjective and they may therefore be subject to intraobserver and interobserver variability (9).

We aimed to determine the effects of knowing chronological age on intra/ interobserver variability of pediatric bone age determination by using the Greulich and Pyle method.

MATERIAL AND METHOD

Plain left hand radiographs were obtained from children who came to pediatric outpatient department during 1 year. Study group was consisted of the cases with suspected trauma, patients receiving short term hormonal therapy (such as undescended testis) and cases who admitted for forensic bone age estimation.

Subjects included in this study fulfilled the following criteria:

1- The cases have no chronic disease or no drug using for long term.

2- No clinical evidence of growth disturbances, with values of body size and weight between the 25th and 75th percentile for a normal age-related population.

3- Normal findings on the radiograph of the left hand with neither bone (including fracture) nor soft tissue abnormalities.

115 boys (chronologic age range, 3-198 months; mean, 70.61±52.38 months) and 113 girls (chronologic age range, 2-186 months; mean, 67.38±47.62 months) were consisted study group.

Informed consent approved by the hospital local ethics committee was obtained from all parents.

Interpretation of the left hand radiographs were made without knowledge and one month later with knowledge of the patient's chronologic age by using second edition of Greulich and Pyle atlas (4) by observers.

To determine the interobserver variability, all radiographs were interpreted by 3 observers (3 radiologists). Radiographs of 23 boys and 27 girls were reevaluated two months later without and with knowledge of chronological ages for determination of intraobserver variability. Results of interpretations were noted. The interval between the readings was one month.

The bone ages within 2 SD of the normative data in the Greulich and Pyle atlas were accepted normal. The bone ages above or below 2 SD were accepted abnormal.

Statistical analysis

Student test for paired samples, kappa and intraclass correlation tests were used for intraobserver statistical comparison by using datas that obtained from interpreters. One way variance analysis (Anova), McNemar and intraclass correlation tests were used for interobserver statistical comparison. SPSS software package is used.

RESULTS

There was no statistically significant inter and intraobserver variability in both basal and second interpretations of hand radiography on average bone age with and without knowledge of chronological ages (paired student t test was made, p>0.05) (Table 1a, 1b).

Table 1a. *Average bone age with and without knowledge of chronological ages (basal interpretation)*

Observers	No Knowledge Mean (Month)	SD (Month)	Range (Month)	Knowledge Mean (Month)	SD (Month)	Range (Month)	*p
1	63.42	49.63	1-204	62.71	49.05	1-204	p>0.05
2	63.21	49.97	1-192	64.22	50.10	1-204	p>0.05
3	63.72	50.59	1-204	64.18	49.99	1-192	p>0.05
All	63.45	49.99	1-204	63.70	49.65	1-204	p>0.05
*p		p> 0.05			p> 0.05		

*N=228; Mean chronologic age=69.01±49.99, *p= Paired student t test.*

Table 1b. *Average bone age with and without knowledge of chronological ages (second interpretation)*

Observers	No Knowledge Mean (Month)	No Knowledge SD (Month)	No Knowledge Range (Month)	Knowledge Mean (Month)	Knowledge SD (Month)	Knowledge Range (Month)	*p
1	69.20	52.25	6-192	71.72	54.26	6-192	p>0.05
2	71.42	55.70	6-192	71.54	54.96	6-192	p>0.05
3	71.96	55.27	6-192	72.12	55.29	6-192	p>0.05
All	70.86	54.07	6-192	71.79	54.47	6-192	p>0.05
*p		p> 0.05			p> 0.05		

*N=50; Mean chronologic age=81.38±53, *p= paired student t test.*

Mean chronological age was 69.01±49.99 and 81.38±53 in first and second interpretation, respectively.

In both basal and second interpretations, there was a significant correlation between interpretations with knowledge of chronological age and without knowledge of chronological age (intraclass correlation test performed; p<0.0001) (Table 2).

There was an intraobserver concordance in both basal and second interpretations (kappa test performed) (Table 3).

There was not statistically significant difference between observers according to knowledge of chronological age. When chronologic age was known, all the observers interpreted radiographs as having normal findings more than when the chronologic age was not known, but this was not statistically significant (McNemar test performed, p>0.05) (Table 4). In third observer's second interpretation with knowledge of chronological age, there was a 2% decrease of having normal findings but this was not statistically significant.

There was a statistically significant correlation between chronological ages and estimated ages in both basal and second interpretations with and without knowledge of chronological ages (p<0.001) (Figure 1-2).

Table 2. *Knowledge condition's effect on basal and second interpretation (correlation)*

Observers	Basal Interpretation		Second Interpretation	
1	r=0.992	p<0.0001	r=0.996	p<0.0001
2	r=0.995	p<0.0001	r=0.992	p<0.0001
3	r=0.993	p<0.0001	r=0.991	p<0.0001

**There was a positive correlation (intraclass correlation test).*

Table 3. *Intraobserver values*

Observers	No Knowledge	Knowledge
1	0.790	0.869
2	0.839	0.871
3	0.660	0.609

**There was an intraobserver correlation in both basal and second interpretation (kappa test).*

Table 4. *Distribution of cases with "normal" findings by observer and knowledge condition*

Observers	Basal Interpretation No Knowledge (%)	Basal Interpretation Knowledge(%)	Second Interpretation No Knowledge (%)	Second Interpretation Knowledge(%)
1	142/228 (62.3)	159/228 (69.7)	30/50 (60)	34/50 (68)
2	139/228 (61)	149/228 (65.4)	27/50 (54)	31/50 (62)
3	152/228 (66.7)	168/228 (73.7)	31/50 (62)	30/50 (60)
All	433/684 (63.3)	476/684 (69.6)	88/150 (58.7)	95/150 (63.3)
*p	p>0.05		p>0.05	

**There was no significant difference (McNemar test).*

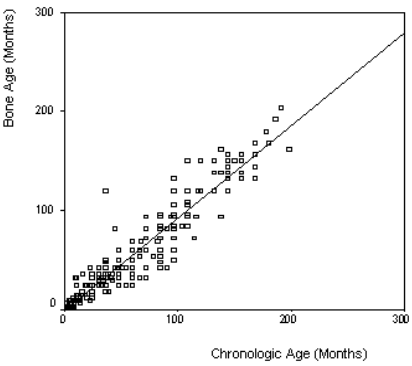

Figure 1A. *No Knowledge.*

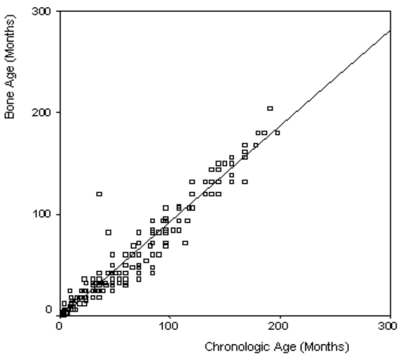

Figure 1B. *Knowledge. Basal interpretation with and without knowledge of chronologic age shows statistically significant correlation between observers estimated bone ages and chronologic ages. (r: 0,945 and r:0,966; p<0.001), N=228.*

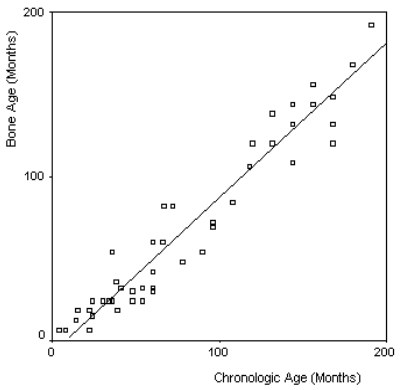

Figure 2A. *No Knowledge.*

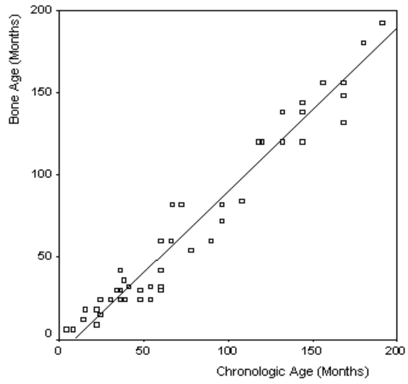

Figure 2B. *Knowledge. Second interpretation with and without knowledge of chronologic age shows statistically significant correlation between observers estimated bone ages and chronologic ages (r: 0,964 and r:0,975; p<0.001), N=50.*

DISCUSSION

In previous studies, where the measured skeletal age was compared with the chronological bone age in children with no evidence of growth abnormalities, the normality of the study populations was mainly verified by a lack of clinical suspicion of abnormalities. This was not confirmed, or correlated with the actual growth values, to guarantee normal growth. Our study was therefore designed to include only those children with known values of growth and weight between the 25th and 75th percentile of a normal age-related population. The subjects could thus be reliably assumed to be normal (9).

The Greulich and Pyle atlas is based on T.Wingate Todd's investigation of left hand and wrist radiographs (5). The method involves directly comparing the radiograph to be assessed with series of standard plates of the same sex by analyzing characteristics such as the appearance of ossification centers, contours of bones, and thinning of growth plates. The standards are stratified by sex and represent the median skeletal maturity for the chronologic age.

The bone-specific approach (Tanner-Whithouse II) assigns a separate rating for each bone of the hand and wrist, with the mean or median rating used as the skeletal age (4). This approach is more accurate, but rarely done. More commonly, the bone age is determined by the closest overall match using a generalized approach and is considered normal if the bone age is within two standard deviations (as provided by the Greulich and Pyle atlas) of chronologic age. Because skeletal development provides the only means of assessing rates of maturational change throughout the growth period, it is imperative to determine the degree of skeletal maturity as accurately as possible (1).

The two methods of bone age assessment as used in clinical practice do not give equivalent estimates of bone age and Bull et al. (10) suggest that one method only should be used when performing serial measurements on an individual patient.

Greulich and Pyle published their data after an analysis of hand radiographs of white upper - class North American children in the 1930s (5). Recent reports show that skeletal maturation may vary over time, between ethnic subgroups, or between children in different geographical locations (11-14).

Mora et al. (12) determined statistically significant difference about skeletal maturity between children of European and African descent in their study. Prepubertal American children of European descent have significantly delayed skeletal maturation when compared with those of African descent. The bone ages of 10% of all prepubertal African descent children were 2 SD above the normative data in the Greulich and Pyle atlas, while the bone ages of 8% of all prepubertal European descent children were 2 SD below. They concluded that the Greulich and Pyle standards imprecise for American children of European and African descent born after 1980.

In a study of Groell et al. (9) the differences between chronological age and bone age were within the normal variations of skeletal maturation as reported by Greulich and Pyle. The mean intraobserver and interobserver variations were lower for experienced readers than for radiology residents in their study. They concluded that Greulich and Pyle method may be used for European children confidentally. Also, Van Rijn et al. (2) reported that Greulich and Pyle atlas may be used for Holland children.

In our study, there was not statistically significant difference between observers according to knowledge of chronological age. There was an intraobserver concordance in both basal and second interpretations. There was a statistically significant correlation between chronological ages and estimated ages in both basal and second interpretations with and without knowledge of chronological ages. When chronologic age was known, all the observers interpreted radiographs as having normal findings more than when the chronologic age was not known, but this was not statistically significant.

If one wants to increase sensitivity, then observers should not know chronologic age when evaluating bone age. However, if one wants to maximize specificity, knowledge of chronologic age is recommended. Ultimately, the decision of whether to access chronologic age before assessment should depend on the consequences of the diagnosis of normal or abnormal (1).

Knowledge of chronologic age does not affect the reliability of bone age assessments. However, observers are more likely to interpret the radiograph as normal when chronologic age is known than when it is not. Therefore, it is important that each radiologist, group, or institution adopt a policy indicating whether each will consistently interpret bone age studies with or without knowledge of the patient's chronologic age (1).

Greulich and Pyle standards is the most common method that preferred for determination of skeletal maturity because it is a basic, rapid and accurate method. As a result, we think that Greulich and Pyle method can be used for determination of Turkish children's skeletal maturity.

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