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Research Article

Comparison of the Reliability of the "GÖK Atlas" and the "Gilsanz-Ratib Atlas" in the Determination of Bone Age in Turkish Children

Türk Çocuklarında Kemik Yaşı Tespitinde "GÖK Atlas" ile "Gilsanz-Ratib Atlas"ın Güvenilirliğinin Karşılaştırılması

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Abstract

Aim: In this study we aimed to evaluate which of the GÖK and GR atlases is more compatible with chronological age in Turkish children aged 5-10 years.

Material and Method: In this study, the wrist radiographs of patients aged 5-10 years who applied to İzmir Bakırçay University Çiğli Training and Research Hospital due to trauma were retrospectively analyzed. A total of 360 wrist radiographs were evaluated. Bone age estimates in both groups were compared with chronological ages.

Results: In the correlation analysis, the prediction rate with 1-difference tolerance is 88.9% in the GR atlas and 76.7% in the GÖK atlas, while both atlases predict 99% correctly with two-difference tolerance. GR Atlas 168 (46.2%) and GÖK Atlas 147 (40.8%) predicted correctly regardless of gender and age. Of the correct estimations, 53.5% in the GR atlas and 57.8% in the GÖK atlas were male cases. İn male age group at the age of 6 and 10, the GR atlas is more successful, at the age of 7, the GÖK Atlas is more successful, and at the age of 5, 8, and 9 the success of both atlases is the same. İn female age group at the age of 5,7, 8, and 10 the GR atlas is more successful, at the age of 6 and 9 the GÖK Atlas is more successful

Conclusion: The GR Atlas was more accurate than the GÖK Atlas. Both the GR Atlas and the GÖK Atlas predicted more accurately in males. Since reference values for bone age can change with environmental and genetic factors all over the world, it is beneficial for all races to create atlas models with multicenter studies in order to establish their own standards.

Keywords: GR atlas, GÖK atlas, Bone age

Öz

Amaç: Bu çalışmada amacımız, 5-10 yaş arası Türk çocuklarında GÖK ve GR atlaslarından hangisinin kronolojik yaş daha uyumlu olduğunu araştırmaktı.

Materyal ve Metot: Çalışmada Bakırçay Üniversitesi Çiğli Eğitim ve Araştırma Hastanesi'ne travma nedeniyle başvuran 5-10 yaş arası hastaların sol el bilek grafileri retrospektif olarak incelendi. Toplamda 180 kız ve 180 erkek çocuğun el bilek grafileri uzman bir radyolog tarafından değerlendirilerek GR ve GÖK atlasları üzerinden kemik yaşı tayini yapıldı.Her iki gruptaki kemik yaşı tahminleri ile kronolojik yaşlar karşılaştırıldı.

Bulgular: Korelasyon analizinde 1 fark tolerans ile tahminleme oranı GR atlasında %88.9 GÖK atlasında %76.7 oranına ulaşmakta iken her iki atlas 2 fark tolerans ile %99 oranında doğru tahminlemede bulunmaktadır. Uyum analizinde cinsiyet ve yaştan bağımsız olarak GR Atlası 168 (%46.2) ve GÖK Atlası 147 (%40,8) doğru tahminde bulunmuştur. Doğru tahminlemelerin GR atlasında %53,5'i GÖK atlasında %57,8'i erkek olgulardır. Erkek olgularda 6 ve 10 yaşında GR atlası daha başarılı, 7 yaşında GÖK atlası daha başarılı, 5, 8 ve 9 yaşında ise her iki atlasın başarısı aynı idi. Kadın olgularda 5, 7, 8 ve 10 yaşında GR atlası daha başarılı, 6 ve 9 yaşında GÖK atlası daha başarılıydı.

Sonuç: GR Atlası, GÖK atlasından daha yüksek oranda doğru tahminlemede bulunmuştur. Hem GR Atlası hem de GÖK Atlası erkeklerde daha doğru tahminlemede bulunmuştur.Kemik yaşı referans değerleri tüm dünyada çevresel ve genetik faktörlerle değişebildiğinden, tüm ırkların kendi standartlarını oluşturabilmeleri için çok merkezli çalışmalarla atlas modelleri oluşturmalarında fayda vardır.

Anahtar Kelimeler: GR atlası, GÖK atlası, Kemik yaşı

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INTRODUCTION

Identification of human parts found in disasters and unknown skeletal remains such as in mass graves is a very important part of forensic studies and is one of the first steps of forensic analysis in these cases. The basic features of identity are generally the age, sex, height, and ethnic origin of the individual (1-4). Bone age determination is a frequently used data for identification, especially in forensic cases, and to support the diagnosis in endocrine disorders. In studies on age estimation, it has been reported that determining bone age can be useful in solving personal, social, and legal problems. If appropriate criteria and methods are not used in age determination, a wrong judgment may be made and a significant loss of rights may could occur as a result (5,6).

Bone age has been shown to be as important as chronological age in the evaluation of an adolescent's physical development (7). Evaluation of skeletal maturity is an important method in the diagnosis, treatment, and follow-up of response to treatment in endocrine disorders (8,9).

It is seen that radiological, morphological, and histological methods are used in age determination in the past, and in recent years, radiological methods are used most frequently. Radiography is one of the most widely used radiological methods in children to evaluate bone age, which is the main indicator of skeletal development (10-17).

Bone age is an indicator of an individual's skeletal and biological maturity. This is different from the chronological age calculated using an individual's date of birth. Bone age estimation is made by radiologists, forensic medicine specialists and pediatricians based on radiological imaging (11,18).

In our country, bone age determination in the pediatric age group is evaluated by forensic medicine physicians with the GÖK Atlas standards, which are often adapted from the Greulich-Pyle Atlas on wrist radiography. In radiology clinics, Giltsanz Ratib (GR), and unmodified Greulich-Pyle (GP) atlases are both available for bone age determination, and preferences vary by institution (5,6,8).

In this study, we aimed to investigate whether the atlases published by GÖK and GR, which are widely used in Turkey, are reliable for use in children aged 5-10 years, and which results are more correlated with their chronological age.

MATERIAL AND METHOD

Population data and grouping

In this study, the wrist radiographs of patients aged 5-10 years who applied to İzmir Bakırçay University Çiğli Training and Research Hospital Emergency Department due to trauma were retrospectively analyzed. Measurements were made on the wrist radiographs of 180 female and 180 male patients aged 5-10 years. Thirty subjects were used for each age of male and female.

Ethics committee approval was obtained for the study numbered 201 dated 4.3.2021 and the decision numbered 219.

Children with endocrinological and metabolic diseases, and with growth and development disorders were excluded from the study, as they may affect the measurement standards and analysis results. The children who were not between 3rd and 97th percentiles according to height and weight standards, determined by Neyzi et al were excluded (19). Cases who were not citizens of the Republic of Turkey were excluded from the study.

Sample landmarks and hand – wrist measurements

The left hand and wrist and for standardization elbow were placed on the extraction table and the third metacarpal bone was centered at a distance of approximately 70-80 cm and exposed in the posteroanterior (P-A) position.

While determining the bone age, the determination was made by deciding the bone age closest to the image over reference points such as the maturation of the bones and the epiphyseal plate on the wrist x-ray (Figure 1).

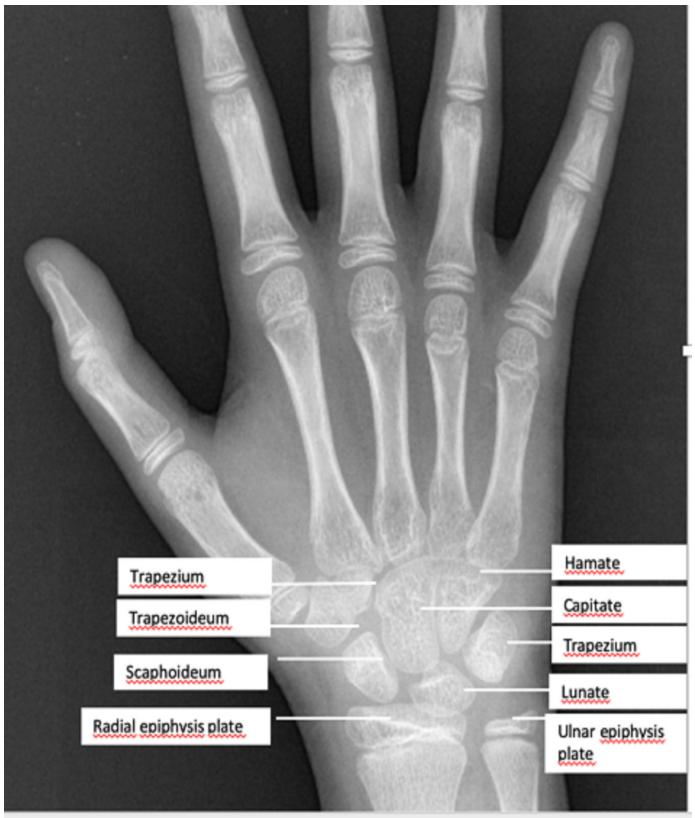

Figure 1. The maturation of the carpal bones, epiphyseal lines and the status of the styloid process used in the determination of bone age in the wrist radiography

Evaluation procedures

First, the chronological ages of the subjects were compared for each gender according to the GR and GÖK Atlas, and in the second step, the differences between chronological and skeletal ages were determined for each age group.

Wrist roentgenograms were compared with the GR Atlas and GÖK Atlas, and the age of the closest picture was taken as the bone age of the film. If the bone age of the film was between two picture ages, but not suitable for both pictures, the age in the completed picture was accepted as the bone age.

All evaluations on X-ray images were performed by the radiologist (ZAO, with at least 5 years of experience evaluating musculoskeletal X-Ray images). For intra-observer reliability, measurements were re-examined under blinded conditions by the same radiologist on the randomly chosen 10% (n= 36) of the images after four weeks.

Statistical analyses

Data collection and statistical analysis were performed with R and SSPS for Windows (version 22; SPSS, Chicago, IL, USA). Agreement correlation (0 tolerance, 1 tolerance and 2 tolerance) were performed to reveal which atlas predicted bone age more accurately for both sexes and for each age range. A randomized review of 36 subjects was performed using KAPPA analysis for within-observer variations.

RESULTS

A total of 360 wrist radiographs of 30 male and female children from every age group between 5-10 years of age were evaluated (Table 1). The intra-observer agreement rate was 94% for both atlases. KAPPA analysis showed that there was a high consistency in age assessment by the same observer in different times.

In the correlation analysis, the GR atlas made 168 (46.2%) correct estimations in general, regardless of sex and age, and made lower estimations in 103 (28.6%) cases and higher estimations in 89 (24.7%) cases according to chronological age (Table 2). The GÖK Atlas made 147 (40.8%) correct estimations in general, regardless of sex and age, and made lower estimations in 69 (19.1%) cases and higher estimates in 144 (40%) cases according to chronological age (Table 2).

Table 1. Distrubition of subjects in each age group

Age (years)	Female	Male	Total samples
5	30	30	60
6	30	30	60
7	30	30	60
8	30	30	60
9	30	30	60
10	30	30	60
Total	**180**	**180**	**360**

When we examined the group in which the GR atlas was correlated with chronological age, 53.5% of the correct predictions were males and 46.5% were females. When we examined the group in which the GÖK atlas was correlated with chronological age, 57.8% of the correct predictions were males and 42.1% were females. Both GR atlas and GÖK atlases made more accurate predictions in males (Table 2).

Estimation rates of correlation with chronological age by age groups GR atlas at 5 years old (38.3%) - GÖK atlas (33.3%), at 6 years old GR atlas (31.6%) - GÖK atlas (35%), at 7 years old GR atlas (48.3%) - GÖK atlas (35%), at 8 years old GR atlas (63.3%) - GÖK atlas (48.3%), at 9 years old (55%) - GÖK atlas (63.3%), at 10 years old GR atlas (43.3%) - GÖK atlas (30%) ; GR atlas is more successful at the age of 5, 7, 8, and 10 years, while GÖK atlas is more successful at 6 and 9 years of age (Table 2).

In male age groups, at 6 years old GR atlas (43.3%) - GÖK atlas (36.6%), at 7 years old GR atlas (40%) - GÖK atlas (53.3%), at 10 years old GR atlas (43.3%) - GÖK atlas (20%) and at 5, 8, and 9 years old, with 56.6%, estimated with same ratio in both atlases correctly. At the age of 6 and 10, the GR atlas is more successful, at the age of 7, the GÖK atlas is more successful, and at the age of 5, 8, and 9 the success of both atlases is the same (Table 2).

Table 2. Agreement correlation analysis (0 tolerans) of GR and GÖK atlases for all ages and genders

	5		6		7		8		9		10	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
CA=GR	17(56.6%)	6(20%)	13(43.3%)	6(20%)	12(40%)	17(56.6%)	23(76.6%)	15(50%)	12(40%)	21(70%)	13(43.3%)	13(43.3%)
CA>GR	10(33.3%)	5(16.6%)	14(46.6%)	10(33.3%)	15(50%)	7(23.3%)	6(20%)	7(23.3%)	12840%)	0	7(23.3%)	10(33.3%)
CA<GR	3(10%)	19(63.3%)	3(10%)	14(46.6%)	3(10%)	6(20%)	1(3.3%)	8(26.6%)	6(20%)	9(30%)	10(33.3%)	7(23.3%)
CA=GÖK	17(56.6%)	3(10%)	11(36.6%)	10(33.3%)	16(53.3%)	5(16.6%)	23(76.6%)	6(20%)	12(40%)	26(86.6%)	6(20%)	12(40%)
CA>GÖK	10(33.3%)	2(6.6%)	14(46.6%)	1(3.3%)	10(33.3%)	3(10%)	6(20%)	0	12(40%)	0	1(3.3%)	10(33.3%)
CA<GÖK	3(10%)	25(83.3%)	5(16.6%)	19(63.3%)	4(13.3%)	22(73.3%)	1(3.3%)	24(80%)	6(20%)	4(13.3%)	23(76.6%)	8(26.6%)
Total	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**

CA: Chronological Age, GÖK: Gök Atlas, GR: Gilsanz- Ratib Atlas

In female age groups, at 5 years old GR atlas (20%) - GÖK atlas (10%), at 6 years old GR atlas (20%) - GÖK atlas (33.3%), at 7 years old GR atlas (56.6%) - GÖK atlas (16.6%), at 8 years old GR atlas (50%) - GÖK atlas (20%), at 9 years old GR atlas (70%) - GÖK atlas (86.6%), and at 10 years old GR atlas (43.3%) - GÖK atlas (40%) estimated correctly. At the age of 5, 7, 8, and 10 the GR atlas is more successful, at the age of 6 and 9 the GÖK atlas is more successful (Table 2).

In the correlation analysis, with 0 tolerance, the GR atlas estimated the bone age 46.2%, 88.9% with 1 difference tolerance and 99.5% with 2 difference tolerance. In the correlation analysis, with 0 tolerance, the GÖK atlas estimated the bone age 40.8%, 76.7% with 1 difference tolerance, and 99.8% with 2 difference tolerance (Table 3).

Table 3. Agreement correlation analysis (0 tolerans) of GR and GÖK atlases for all ages and genders

	0 tolerance	1 tolerance	2 tolerance
CA -GR	46.2 %	88.9 %	99.5 %
CA-GÖK	40.8 %	76.7 %	96.8 %

CA: Chronological Age, GÖK: Gök Atlas, GR: Gilsanz- Ratib Atlas

DISCUSSION

The GR Atlas made 46.2% correct estimations in general, regardless of sex and age, and made lower estimations in 28.6% cases and higher estimations in 24.7% cases according to chronological age. The GÖK Atlas made 40.8% correct estimations in general, regardless of sex and age, and made lower estimations in 19.1% cases and higher estimates in 40% cases according to chronological age. In general, although the GR atlas gave modestly better results than the GÖK atlas, there was roughly similar agreement between both atlases in some age groups.

The GR atlas estimated the bone age 88.9% with 1 difference tolerance and 99.5% with 2 difference tolerance while the GÖK atlas estimated the bone age 76.7% with 1 difference tolerance, and 99.8% with 2 difference tolerance. In the correlation analysis, the percentages of correct estimation of bone age increase approximately two times with "1 tolerance", and again, the GR atlas is more successful, as is the case with zero tolerance. In 2 tolerances, both atlases make similar and fairly accurate estimations.

We see that in the GÖK atlas, no sex discrimination was made between the ages of 5-10, and the same ossification criteria were accepted for male and female children. However, there are separate criteria according to sex in GR Atlas. It has been observed that GR atlas makes more descriptive definitions in this age range.

In our study for males, GR and GÖK atlases are equally accurate in the 5, 8, and 9 age groups, while GR is more successful in the 6 and 10 age groups, GÖK is more successful at the age of 7. The predictions for females are more accurate in the 5, 7, 8, and 10 age groups in the GR atlas, while GÖK was more accurate at 6 and 9 years old. Both the GR atlas and the GÖK atlas made more accurate predictions in males. Opposite of this in the study of Baransel Isır et al., it was reported that chronological age and bone age did not correlate in males and there was a significant discrepancy (20). While the GR atlas is more compatible with the chronological age in the 5, 7, 8, and 10 age groups, the GÖK Atlas is compatible in the 6 and 9 age groups. In the age estimation study by Büken et al. using the GÖK Atlas, it is reported that the difference between chronological age and bone age in both male and female is more than one year and it is reported that the reliability index of the GÖK Atlas, which is generally used in Turkey, is not sufficient (11).

The fact that both atlases are based on populations of European origin and do not include the Turkish population may explain the trend of similar results. It has been reported that there are many studies indicating that these atlases are not suitable for use in Turkish children (6). Although there are some anthropometric studies on individuals living in our country, there is no widely accepted atlas of age estimation conducted on Turkish people.

Forensic age determination is one of the important topics of forensic science. For unidentified and suspicious deaths and child deaths, and for those living in a situation who cannot express themselves, age determination may be requested by the judicial authorities (10). GÖK Atlas, which Şemsi Gök et al. prepared in 1985, adapted from the GP Atlas, is widely used in Forensic Medicine practices for age estimation. The Greulich-Pyle (GP) Atlas has been prepared in white children from a high socioeconomic level, who were born between 1917 and 1947 in the USA (20-22). Racial, socioeconomic, and environmental differences between Turkish children and the group of children which the GP Atlas was derived may result in differences in sexual development and skeletal maturation.

In order to avoid legal consequences, we tried to reveal which of the existing atlases is more suitable for the Turkish population. The digital era, it is easier to produce a new atlas than before. Because bone development varies with ethnicity, geography and time, radiologists around the world could make their own atlases in the same way.

One of our limitations in the study was that the entire patient population consisted of patients in the province of İzmir, and although İzmir is one of the largest provinces,

it was not an optimal sample group to reflect the Turkish population due to its western location. Therefore, a multicenter evaluation is needed.

While it was possible to make a more detailed comparison of 3-4 images in the anterior-posterior and lateral projections for both genders in the GR atlas, another limitation of the GÖK atlas was the age determination based on only one image and a written text, regardless of gender.

CONCLUSION

The aim of our study is to evaluate how compatible the standards of GR and GÖK Atlases are with chronological age in Turkish children. In general, both the GR Atlas and the GÖK Atlas made more accurate predictions in men. While GR Atlas was more accurate than GÖK Atlas in the estimations made with 0 and 1 tolerance, the estimations made with 2 tolerances were almost completely correct and similar in both atlas. It may be practical to use GR or GÖK Atlases according to the age and gender of the children.

Since reference values for bone age can change with environmental and genetic factors all over the world, it is beneficial for all races to create atlas models with multicenter studies in order to establish their own standards.

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Conflict of Interest: *The authors declare that they have no competing interest.*

Ethical approval: *Izmir Bakircay University ethics committee for non-interventional clinical trials it has been approved by decision. Decision no: 219, Date: 04.03.2021*

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