Turkish Journal of Medical Sciences

Volume 38 | Number 4 Article 6

1-1-2008

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TÜBİTAK

ORIGINAL ARTICLE

Turk J Med Sci
2008; 38 (4): 319-327
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Is the "Gök Atlas" Sufficiently Reliable for Forensic Age Determination of Turkish Children?*

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Received: September 21, 2007
Accepted: May 05, 2008

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Aim: We investigated whether the contemporary use of the Gök Atlas method is sufficiently reliable for forensic age estimations of Turkish children.

Materials and Methods: Plain radiographs of 248 females and 298 males between 11 and 22 years of age were taken. Paired sample t-tests, Pearson correlation coefficients, and linear regression were used to determine the differences and model the relationships between mean skeletal (bone) age (BA) and mean chronological age (CA), using SPSS 11.5 statistical software.

Results: In all cases, the CA and BA scores were significantly different and showed high correlation ($P < 0.05$). The regression model was significant ($P < 0.01$). According to age groups, the BA was greater than the CA for all age groups by 0.09–3.10 years for boys and 0.44-3.05 years for girls, and this difference was significant for all age groups >14 years for boys and for those 11-18 years of age for girls. The standard deviation of the difference between BA and CA for boys between 11 and 18 years of age and for girls between 11 and 20 years of age was >1 year.

Conclusions: We found a large discrepancy between CA and BA according to the Gök Atlas. This discrepancy may be significantly misleading, especially in criminal liability cases.

Key Words: Age estimation, bone age, Gök Atlas method, skeletal maturation, Turkish children

Günümüz Türk Çocuklarında Adli Tibbi Yaş Tayini İçin "GÖK Atlası"nın Kullanımı Yeterince Güvenli mi?

Amaç: Bu çalışmada GÖK atlas metodunun adli tıbbi yaş tayininde, günümüz Türk çocukları için yeterli olup olmadığı araştırmaktadır.

Yöntem ve Gereç: 11-22 yaş arasında 298 erkek 248 kız, sağlıklı çocuğun planlı radyografileri çekildi. Ortalama kronolojik yaş (CA) ve GÖK Atlas metoduna göre elde edilen ortalama iskelet yaşı (BA) arasında ki farkları saptamak ve ilişkiyi modellemek için paired sample t test, pearson korelasyon and regresyon analizi kullanıldı. Analizler SPSS 11.5 ortamında gerçekleştirildi.

Bulgular: CA ve BA karşılaştırıldı. Çalışmaya katılan tüm olgular yaş gruplarına ayrılmaksızın ele alındığında her iki cinsiyette fark istatistiksel olarak anlamlı idi ($P < 0.05$). Yüksek korelasyon vardı. Determinasyon katsayısı (R^2) erkeklerde 0.861, kızlarda 0.625'e eşitti. Regresyon modeli anlamlı bulundu ($P < 0.01$). Fakat yaş gruplarına göre, Tüm yaş gruplarında erkeklerde BA (0.09-3.10 yıl arasında) ileri ve 14 yaşın üstünde tüm çocuklarda fark istatistiksel olarak anlamlı, kızlarda BA (0.44 - 3.05 yıl) ileri ve 11-18 yaş arasında kız çocuklarda fark istatistiksel olarak anlamlı idi. Erkeklerde 11-18 , kızlarda 11-20 yaş arasında tüm yaş gruplarında farkların standart sapması 1 yıldan daha fazla idi.

Sonuç: Biz CA ve GÖK atlasına göre saptanan BA arasında yaş gruplarına gore her iki cinsiyette büyük bir farklılık saptadık. Bu farklığın özellikle ceza sorumluluğuyla ilgili olarak yaş tayini yapılan olgularda önemli hak kayıplarına neden olabileceği düşünülmektedir.

Anahtar Sözcükler: Yaş tayini, Kemik yaşı, İskelet gelişimi, Türk çocuklar, GÖK atlas metodu

* This study was supported by the Abant İzzet Baysal University research fund.

Introduction

Age determination is one of the most important factors for human identification. Age estimation studies indicate that identification procedures are not only useful in solving personal or social problems, but can also have international ramifications. At the Institute of Legal Medicine of Berlin University, 7% of the forensic age assessments were of Turkish people (1). Age determinations have been requested from courts of law for Turks living in various foreign countries, particularly in Europe. Incorrect evaluations can cause severe legal problems. When appropriate criteria are not used in forensic age determinations, a significant loss of rights can occur in sentencing and in legal judgments (2-4).

Minors are subject to special Turkish national and community regulations that are different from those applied to people over 18 years of age. According to these regulations, minors under 12 years of age are exempt from criminal liability, whereas minors between 12 and 15 and between 15 and 18 years of age are subject to special age-related criminal standards. According to civil codes, an individual begins adulthood when he or she attains 18 years of age. Boys and girls cannot marry until they have reached 18 years of age, although under extenuating circumstances, a judge can give permission for boys and girls of 16 years to marry. In addition, in the penal code, any kind of sexual behavior is defined as exploitation when it involves children who are younger than 16 years. If the contents of the law are taken into consideration, the age categories of younger than 12, 15, and 18 years affect many aspects of the law from sentencing to civil rights (5,6).

In Turkey, the evaluation of age for legal purposes is conducted by pediatricians, radiologists, and forensic medicine specialists. A survey of forensic medicine specialists indicated that 45.7% use the Gök Atlas, 21.7% use the Greulich-Pyle (GP) method, and 17.4% rely on the Tanner-Whitehouse method (7). Very few studies have evaluated the appropriateness of these methods for use in Turkish children (8,9). Despite its widespread use, we found no published studies of whether the Gök Atlas is appropriate for use in the age determination of Turkish children.

Numerous international studies have reported that racial differences affect growth and development and that over time, differences in growth and development also occur in communities in which studies have been conducted. This necessitates making adjustments in the values that are currently used in age evaluations (10,11). Therefore, our purpose was to investigate whether the atlas published by Gök et al. (2), which is widely used in Turkey, is reliable for contemporary use in Turkish children. Here, we present our results for Turkish boys and girls.

Materials and Methods

Twelve schools in Central Düzce, Turkey, were sampled randomly. A total of 1200 children (boys and girls) who were born and registered in local hospitals were randomly chosen from these schools. Informed consent was obtained from the parents of 772 children who were then included in our study. Children from 11 to 22 years of age with no past history of chronic or severe systemic illness and without previous history of trauma or injury at the measured joints and bones were selected for study. Height was measured to the nearest 0.1 cm using a height scale, and weight was measured to the nearest 0.1 kg using an electronic weighting scale (SECA, Hamburg, Germany). The children were between the 3rd and 97th percentiles according to height and weight standards determined by Neyzi et al. (12). The staging system developed by Tanner was used to assess the patterns of penile and testicular features, pubic hair in the boys, and breast development, pubic hair in girls (13,14).

All children were examined by a physician to exclude the possibility of any diseases that might have affected their physical growth. The study group comprised 546 subjects who met the study criteria: 248 (45.4%) females and 298 (54.6%) males (12,15). A questionnaire was completed by the parents of each child to obtain demographic data. The same physician conducted genital examinations and measurements, and the study director reexamined some of the subjects to maintain standardization and reliability.

Conventional roentgenograms of left hands and wrists, shoulder, elbow, and pelvis were taken. The roentgenographic examinations were done by Trophy radiograph using green-sensitive, 18 × 24, 24 × 30, and 30 × 40 film (Kodak). Exposure doses were calculated according to age, zone of exposure, and tissue thickness. The exposed doses ranged from 46 to 80 kV and 6.5 to

25 mAs. All radiographs were compared with the Gök Atlas by an independent forensic medicine specialist who is currently responsible for legal cases involving age determination. During the evaluation, the physician (forensic specialist) was informed only of the sex of the child. The concordance between two readings of the researcher (forensic specialist) was evaluated by computing the intraclass correlation coefficient (ICC). The ICC for boys was r = 0.970 (n = 51) and for girls was r = 0.999 (n = 60).

The mean chronological age (CA) of subjects was compared to the mean skeletal (bone) age (BA) according to the Gök Atlas using a paired *t*-test, and their correlation was evaluated using the Pearson correlation coefficient. Linear regression was used to model the relationship between CA and BA according to the Gök Atlas. The subjects were then divided into yearly age groups, and the differences between the CA and BA were determined for each age group, as in previous studies (4). The statistical analyses were conducted using SPSS 11.5 software.

This study was approved by the Hospital Ethics Committee of Abant Izzet Baysal University, Turkey, and was supported by a research fund from the university.

Results

Boys

The mean ± SD chronological age (CA) of boys was 16.17 ± 3.11 years (SE: 0.15, median: 15.93, range: 11.13–23.76 years), whereas the mean ± SD skeletal age (BA) was 17.49 ± 3.87 years (SE: 0.18, median: 19.00, range: 10.00–22.00 years; Table 1a). The difference between CA and BA was 1.32 ± 1.98 and statistically significant ($P < 0.001$). The standard deviation of BA was greater than the standard deviation of CA. BA was lower than the CA in 21 boys (7.0%), equal to the CA in 65 boys (21.8%), and greater than the CA in 212 boys (71.1%). The measured growth factors were highly correlated with CA and BA (Table 2a). There was a high correlation (Pearson r = 0.861; $P < 0.001$) between the mean CA and the mean BA (Table 2a), but according to age groups, significant correlations occurred for boys aged 12 and 13 (Table 3a). For boys between 11 and 22 years of age, the mean BA was greater than the mean CA for all ages except 22-year-olds, and was significantly greater in boys aged 15 and over.

Epiphyseal union was complete for 10.3%, 15.2%, 33.3%, 41.2%, 39.1%, 66.7%, 93.8%, and 100% of boys aged 15, 16, 17, 18, 19, 20, 21, and 22,

Table 1a. Mean age and anthropometric characteristics of Turkish boys (n = 298).

Characteristic	Mean ± SD	Median
Chronological age	16.17 ± 3.11	15.93
Skeletal age	17.49 ± 3.87	19.00
Weight (kg)	60.74 ± 17.94	59.4
Height (cm)	164.22 ± 14.39	167.2

Table 1b. Mean age and anthropometric characteristics of Turkish girls (n = 248).

Characteristic	Mean ± SD	Median
Chronological age	14.89 ± 2.55	14.71
Skeletal age	17.77 ± 3.04	18.00
Weight (kg)	51.27 ± 10.02	52.5
Height (cm)	154.94 ± 8.66	156.1

Table 2a. Correlation of chronological age and skeletal age with sexual maturation criteria for Turkish boys.

Characteristic	Chronological age (CA)		Skeletal age (BA)	
	r	p	r	p
Pubic hair	0.730	0.000	0.861	0.000
Genital development	0.726	0.000	0.806	0.000
Skeletal age	0.861	0.000	1	–

Table 2b. Correlation of chronological age and skeletal age with sexual maturation criteria for girls according to Tanner.

Characteristic	Chronological age		Skeletal age	
	r	p	r	p
Pubic hair	0.691	0.000	0.745	0.000
Breast development	0.549	0.000	0.614	0.000
Menarche	0.626	0.000	0.716	0.000
Skeletal age	0.791	0.000	1	–

Table 3a. Mean ± SD chronological age (CA) and skeletal age (BA) of Turkish boys and differences between CA and BA according to age (paired *t*-test).

Age groups	N	Mean CA	Mean BA (Gök)	Difference CI: 95%	*t*	P value	Correlation	
							r	p
11	25	11.47 ± 0.25	11.84 ± 0.99	–0.37 ± 1.09	–1.69	0.104	–0.295	0.153
12	26	12.45 ± 0.26	12.80 ± 1.47	–0.35 ± 1.34	–1.36	0.186	0.557	0.003
13	34	13.46 ± 0.30	13.56 ± 1.52	–0.09 ± 1.41	–0.39	0.699	0.446	0.008
14	39	14.57 ± 0.24	15.15 ± 2.43	–0.58 ± 2.39	–1.51	0.138	0.232	0.155
15	29	15.52 ± 0.31	18.62 ± 2.33	–3.10 ± 2.38	–6.98	0.000	–0.099	0.608
16	33	16.50 ± 0.29	19.15 ± 1.75	–2.64 ± 1.73	–8.76	0.000	0.139	0.442
17	27	17.40 ± 0.32	20.48 ± 1.39	–3.08 ± 1.39	–11.51	0.000	–0.135	0.501
18	17	18.46 ± 0.30	20.71 ± 1.53	–2.23 ± 1.52	–6.07	0.000	0.137	0.600
19	23	19.43 ± 0.29	20.82 ± 1.02	–1.39 ± 1.00	–6.67	0.000	–0.237	0.277
20	21	20.54 ± 0.31	21.33 ± 1.01	–0.79 ± 0.25	–3.20	0.004	–0.222	0.334
21	16	21.48 ± 0.29	21.93 ± 0.25	–0.45 ± 0.32	–5.61	0.000	0.280	0.294
22	8	22.62 ± 0.29	22.00 ± 0.00	0.62 ± 0.29	6.15	0.000	–	–

Table 3b. Mean ± SD chronological age (CA) and skeletal age (BA) of Turkish girls and differences between CA and BA according to age (paired *t*-test).

Age groups	N	Mean CA	Mean BA (Gök)	Difference CI: 95%	*t*	P value	Correlation	
							r	p
11	39	11.52 ± 0.28	13.43 ± 1.62	-1.91 ± 1.57	- 7.60	0.000	0.252	0.121
12	35	12.57 ± 0.30	15.42 ± 1.69	-2.85 ± 1.64	- 10.23	0.000	0.212	0.221
13	29	13.50 ± 0.28	16.55 ± 2.01	-3.05 ± 2.14	- 8.23	0.000	0.132	0.496
14	35	14.58 ± 0.27	18.68 ± 1.59	-4.11 ± 1.51	-16.07	0.000	0.351	0.038
15	24	15.43 ± 0.34	18.67 ± 1.09	-3.24 ± 1.17	-13.58	0.000	-0.082	0.705
16	31	16.46 ± 0.29	20.32 ± 1.62	-3.86 ± 1.62	-13.26	0.000	-0.086	0.645
17	23	17.50 ± 0.36	20.34 ± 1.66	-2.84 ± 1.62	- 8.38	0.000	0.225	0.302
18	16	18.27 ± 0.23	20.31 ± 1.82	-2.03 ± 1.82	- 4.45	0.000	-0.004	0.988
19	8	19.54 ± 0.20	20.50 ± 1.60	-0.95 ± 1.75	- 1.54	0.167	- 0.725	0.042
20	4	20.55 ± 0.08	21.00 ± 1.41	-0.44 ± 1.45	- 0.69	0.580	-0.403	0.597
21	4	21.51 ± 0.25	22.00 ± 0.00	-0.49 ± 0.25	- 3.90	0.030	-	-

respectively. Epiphyseal union was complete for all boys over 21 years of age.

The coefficient of determination (R) was 0.861, indicating that 86.1% of the variation in Gök (BA) can be explained by CA. The regression model, tested by analysis of variance (ANOVA), was significant ($P < 0.01$). The intercept of the regression was 0.156 and was significant ($P > 0.05$). The slope of the regression was 1.072 and was also significant ($P < 0.01$). For boys, the Gök Atlas method has a 0.156-year backward shift for the model and every year of CA increases the Gök-based estimation by a rate of 1.072 (Figure 1a).

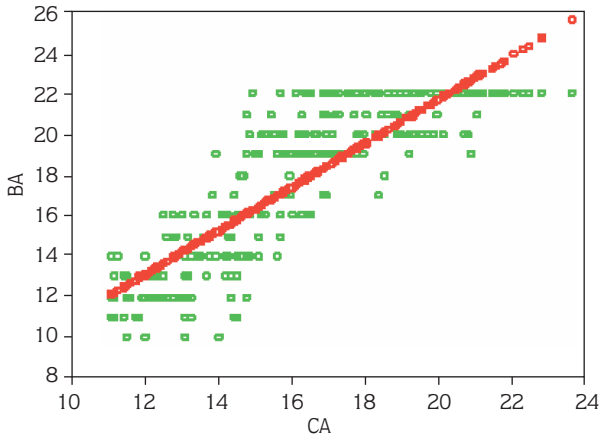

Figure 1a. Regression model of chronological age (CA) and skeletal age (BA) according to the Gök Atlas for Turkish boys (R^2 = 0.861).

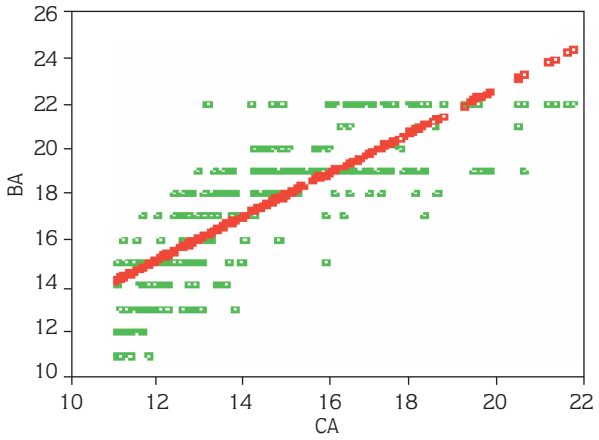

Figure 1b. Regression model for girls, R^2 = 0.625. CA: chronological age; BA: skeletal age according to Gök Atlas.

We also examined the distribution of sexual maturation criteria by age (Table 4a). The family incomes were less than minimum wage for 45.5% of boys and greater than the average income for 6.4% of boys. The boys' nutrition was based on diets consisting of vegetables and foods made with flour.

Girls

The mean CA of girls was 14.89 ± 2.55 SD years (SE: 0.12, median: 14.71, range: 11.06 - 21.77 years), whereas mean BA according to the Gök Atlas was significantly higher, at 17.77 ± 3.04 SD years (SE: 0.11, median: 18.00, range: 11 - 21 years; $P < 0.001$; Table 1b). BA was less than the CA in only 2 girls (0.8%), equal in 15 (6.0%), and greater than the CA in 231 (93.1%). There was a high correlation (Pearson $r = 0.791$; $P < 0.001$) between CA and BA for all girls, but when analyzed according to age group, significant correlations were found only at 14 years of age (Tables 2b-3b). The growth factors showed high correlations with both CA and BA (Table 2b).

CA and BA of girls were compared according to age group (Table 3b). In the age groups of girls between 11 and 21 years old, BA was advanced compared to CA for all age groups. P values were statistically significant for all ages except 19- and 20-year-old subjects.

Radiographs showed complete epiphyseal union in 3.4%, 8.6%, 0%, 41.9%, 47.8%, 43.8%, 50.0%, and 50.0% of girls in each age group from 13 to 20 years old, respectively. For 15-year-olds, there were no cases of complete epiphyseal union, but epiphyseal union was complete in all subjects over 20 years of age.

To model the relationships between BA and CA, the linear regression method was used, where CA and BA were the independent and dependent variables, respectively. The determination coefficient (R), which represents the fraction of variability in y that can be explained by the variability in x, was 0.625; thus, 0.625% of Gök (BA) variation could be explained by CA. The regression model was also tested by ANOVA and was found to be significant ($P < 0.01$). The intercept and slope of the regression model were 3.769 and 0.942, respectively, and both were significant ($P < 0.01$). Thus, for girls, the Gök Atlas method has a 3.7-year forward shift for the model, and every year of CA increases the Gök-based estimation at a rate of 0.942 (Fig. 1b).

The percentage of no menarche was 27.8% for all subjects, 87.2% at 11 years, 60.0% at 12 years, 41.4% at 13 years, and 5.7% at 14 years; all girls older than 14 years had menarche.

The family incomes of 39.5% of the girls were below minimum wage, whereas those of only 3.6% were above average.

We also examined the distribution of sexual maturation criteria (Table 4b).

The subjects' nutrition was based on diets consisting mainly of vegetables and foods made with flour.

Table 4a. Distribution of subjects according to Tanner's sexual development criteria for boys.

Criterion	Stage 1		Stage 2		Stage 3		Stage 4		Stage 5	
	n	%	n	%	n	%	n	%	n	%
Pubic hair	37	12.4	36	12.1	38	12.8	153	51.3	34	11.4
Penis and testis development	38	12.8	35	11.7	38	12.8	154	51.7	33	11.1

Table 4b. Distribution of subjects according to Tanner sexual development criteria for girls.

	Stage 1		Stage 2		Stage 3		Stage 4		Stage 5	
	n	%	n	%	n	%	N	%	n	%
PH	25	10.1	31	12.5	68	27.4	103	41.5	21	8.5
BD	18	7.3	55	22.2	71	28.6	89	35.9	15	6.0

PH: pubic hair; BD: breast development.

Discussion

Physicians are often requested to assess the age of an individual in civil and criminal cases. The study of the epiphyseal union of bones is considered a reasonable scientific and accepted method of age estimation by courts of law worldwide (16). Skeletal age determination is usually performed by comparing the plain radiograph of a patient with findings in a normal reference population (17,18). The Gök Atlas method is the most commonly used by forensic specialists in determining skeletal maturity from X-rays in Turkey (7). Using the Gök Atlas, the skeletal ages of boys between the ages of 11 and 22 were determined by examining the degree of epiphyseal fusion of shoulder, elbow, hand and wrist, and pelvic bones (2). Our objective was to determine whether the Gök Atlas is sufficiently accurate for estimating the age of Turkish boys and girls for forensic purposes.

It should be kept in mind that clear medico-legal statements about age cannot be made from radiographs alone (19). Of the forensic methods recommended for age estimation, the evaluation of sexual maturity shows the largest range of variation and therefore should be used for age determination only in conjunction with an evaluation of skeletal maturity (20). Age estimations should involve careful examination of anthropometric data, signs of sexual maturation, and potential age-relevant developmental disorders (19). Therefore, we assessed the degree of sexual maturation, age, and anthropometric characteristics of all of the subjects in our study (Table 1).

According to DIE (Republic of Turkey, Turkish Statistical Institute), the average monthly income for a family in Düzce in 2001 was 1242 YTL (approximately $750 U.S.) (21). The family incomes were less than minimum wage for 45.5% of boys and above the average income for Duzce for 6.4% of boys. The monthly minimum wage in Turkey was 480 YTL (approximately $350 U.S. dollars) in 2005 (20). Thus, the boys in our study population had low to moderate socioeconomic status. Although extreme situations of poverty and malnourishment can lead to pronounced delays in skeletal maturation (17), our study was designed to only include subjects with age-related height and weight between the 3rd and 97th percentile of a normal population. These standards were determined by Neyzi et al. (12) for Turkish children. Therefore, the subjects could be reliably assumed to be developmentally normal. Thus, poverty likely had little influence on our results and was not a cause of undernourishment in our study population.

Although the Gök Atlas is used by approximately 50% of forensic medicine specialists (7), no studies have been published on its relevance since its publication. Therefore, we were unable to compare our results with others.

We found significant differences between CA and BA for the entire group of boys and girls ($P < 0.001$). According to age groups, the mean BA was greater than the mean CA by 0.09–3.10 years for all ages groups and was significantly greater for boys older than 14 years (Table 3a). Mean BA was advanced (0.44-3.86 years) for all ages, and differences were significant at all ages except for 19-20 years for girls (Table 3b). Methods for age estimation accepted by courts of law worldwide offer reliability ranges. For example, Groell et al. (17) showed that there is a discrepancy of up to 1 year between CA and measured BA and confirmed that the GP method may reliably be applied to Central European children. However, there is no previously determined reliability range for the Gök Atlas method. In particular, we found differences >1 year for boys between 15 and 19 years of age and for all girls between 11 and 18 years of age. It was >3 years between 13 and 16 years of age. The differences between BA and CA gradually increased between 11 and 14 years of age for girls. We think that a suitable discrepancy range should not exceed 1 year; thus, the discrepancy for the Gök Atlas method is unsuitable for forensic age estimations. For this reason, we recommend that this method not be used for age estimations of early post-pubertal boys and of girls between the ages of 11 and 18.

The difference between CA and BA was <1 year (0.09–0.58 years) for boys between 11 and 14 years and was not statistically significant. However, the difference between CA and BA was >1 year for boys between 14 and 19 years and was statistically significant (Table 3a). This greater difference may be explained by puberty. According to Rikhasor et al. (22), the age limit for skeletal growth retardation is 15 years for boys, and this age is approximately at or around the time of puberty for boys. In our study, boys' skeletal maturation accelerated after 14 years of age.

The difference between the BA and CA was <1 year (0.44 - 0.95 years) for girls at the ages of 19, 20, and 21, but that of the other age groups was >1 year (Table 3b). We are uncertain about the reliability for subjects older than 19 years in our study, because the epiphyseal union was completed after age 19 in >50% of our cases, and the number of cases in which it was not complete in these age groups was insufficient for a complete analysis.

According to Rikhasor et al. (22), the age limit of skeletal retardation in Pakistani girls was 13 years. The age of puberty for Turkish girls was similar according to Akarsu et al. (23), whereas in our study, all girls older than 14 years had menarche and were skeletally mature. The distribution of sexual maturation criteria with skeletal development and the correlation between CA and sexual maturation criteria are shown in Tables 2b and 4b.

We are uncertain about the reliability of the Gök Atlas method for boys older than 20 years because the epiphyseal union was complete by the age of 20 for >50% of boys. The overall correlations were high (i.e., boys of all ages combined; Table 2a), but this may be misleading because correlations for the separate ages were very low and were significant only for boys 12 and 13 years of age (Table 3a) and average only for 14-year-old girls (Tables 2a-b and 3a-b). For this reason, this method does not appear to be technically useful for forensic age estimation in Turkish girls and boys.

Greulich and Pyle (24) identified standard deviations ranging from 0.6 to 1.1 years for their method, but no range was given for the Gök Atlas method. If we accept these criteria as Gök Atlas criteria, we would not be able to use this method for boys between 11 and 19 years old and especially for those of 14 and 15 years and for girls between 11 and 20 years old.

Many recent studies have indicated a comparative acceleration of skeletal maturity in Western and other populations. The cause of this acceleration could be new sociocultural factors rather than economic conditions (23,24). The Gök Atlas was last published in 1985, and its initial publication was in 1969. Gök et al. (2), in the atlas preface, state that the atlas can be used for Turkish children, but there have been major changes in the Turkish population since 1969 caused both by economic and sociocultural factors. This large discrepancy in CA and BA could have arisen from these causes.

Our results are very important for Turkish children who live in Turkey and in foreign countries. Age determinations have been requested from the courts for some Turks living in various foreign countries, particularly in Europe. Thus, incorrect evaluations could cause legal problems to arise outside the country. For this reason, nationwide studies need to be conducted as soon

as possible to determine an appropriate atlas for age estimation in Turkish children. As a short-term solution, it is necessary to determine the appropriateness of internationally accepted atlases for Turkish children and to make adaptations to atlases for Turkish children.

Our study has several limitations. The children that were enrolled in our study were all from Düzce province; thus, differences that may be related to geographic location or climate were minimized. Racial and climatic differences are very high among geographical regions in Turkey. Therefore, we recruited our study population only from the Black Sea region of Turkey. However, this study should be repeated in other regions of Turkey, and we hope that our results will encourage other forensic researchers to do so.

We could not determine hormone levels (e.g., FSH, LH, testosterone) because of economic limitations and ethical considerations. We could not determine tooth development because we did not have orthopantography equipment; this equipment is not available in our hospital or in our province. We planned the study according to Neyzi's standards (12), which reflect Turkish children, but these standards do not include adults.

An advantage of our study is that it was designed to avoid the effects of growth retardation and obesity on skeletal maturation by using only children with age-related height and weight between the 3rd and 97th percentiles for the general population. In addition, we determined the degree of sexual maturation of all candidates to account for the confounding effect of puberty on skeletal maturation. Lastly, bone determination was analyzed by a forensic medicine specialist who is very experienced in the practice of age estimation to minimize subjectivity and interobserver variability. All cases were evaluated twice. When the analysis results were discordant, these cases were re-evaluated and the results were registered as decisive. This was necessary to produce good results. The strong concordance in evaluations is a reflection of proficiency and confirms indications that bone age estimations improve with clinical experience (4).

A Final Note

To our knowledge, this type of study has not been conducted previously for this atlas. We found a large discrepancy between BA and CA for all cases combined and in separate ages for both sexes. This discrepancy may be misleading, especially in criminal liability cases. This is an important human rights problem for Turkish children. This atlas should not be used particularly for subjects between 15 and 18 years of age for forensic age estimations in criminal liability cases.

We found less discrepancy between CA and BA for Turkish boys using the same statistical method in comparable cases in a previous study (4). Therefore, we suggest that the Greulich-Pyle Atlas should be used instead of the Gök Atlas for boys and girls, particularly those between 11 and 18 years of age.

Acknowledgements

This study was supported by the Abant Izzet Baysal University research fund. A portion of this study was presented as a poster presentation at the Fifth National Forensic Science Congress, Samsun, Turkey. We thank the Düzce Ministry of Education and Prof. Dr. Kenan Kocabay for their support and Dr. Filiz Demir and Dr. Ali Koyuncuer for their assistance in the measurement phase of this study.

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