

Age Determination in Turkish People Based on the Calcification Degree of the First Costal Cartilage

Türk İnsanında Birinci Kostal Kartilajın Kalsifikasyon Derecesi Temelinde Yaş Tayini

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ABSTRACT Objective: While developed countries do age estimation for the purpose of identification, in countries such as Turkey, it is used to determine the real age of a person with an already known identity because of inaccurate birth records. The aim of this article was to investigate whether the calcification degree of the first costal cartilage could be a marker for age determination. **Material and Methods:** We retrospectively analyzed the postero-anterior chest x-rays of 471 patients (270 males, 201 females; mean age \pm standard deviation 42.38 \pm 20.69 years) who presented to the radiology department for various reasons. The calcification degree of the right first costal cartilage was classified in four stages based on criteria used by Barchilon and Garamendi, and the patients were classified in seven groups regarding their ages. The correlation between the calcification stage of the right first costal cartilages and age group was analyzed by Spearman's rho. **Results:** According to the first costal cartilage calcification stage, the mean ages were 5.56, 25.49, 45.39 and 66.02 at stage 0, 1, 2 and 3, respectively. The calcification degree of the right first costal cartilage and age correlated significantly in males and females [Spearman's rho=0.904, $p<0.001$ (0.924, $p<0.001$ in males and 0.864, $p<0.001$ in females)]. **Conclusion:** Although there are overlaps among age groups, the assessment of the calcification degree of the first costal cartilage on chest x-rays may be useful to predict the bone age. This age determination method can be used in criminal courts and forensic anthropology as a contributory technique.

Key Words: Forensic medicine; radiography; thorax; age groups

ÖZET Amaç: Yaş tespiti, gelişmiş ülkelerde kimlik tayini amacıyla yapılsa da, Türkiye gibi bazı ülkelerde, güvenilir olmayan nüfus kayıtları nedeniyle kimlik tayininden ziyade kimliği bilinen kişilerin gerçek yaşlarının tespiti için yapılmaktadır. Bu çalışmanın amacı, birinci kosta kırırdağının kalsifikasyon derecesinin yaş tayininde kullanılıp kullanılmayacağını araştırmaktır. **Gereç ve Yöntemler:** Çeşitli nedenlerle postero-anterior göğüs radyografisi ile değerlendirilen 471 hastanın (270 erkek, 201 kadın; ortalama yaş \pm standart sapma 42,38 \pm 20,69 yıl) grafileri retrospektif olarak incelendi. Birinci sağ kosta kırırdağının kalsifikasyon derecesi, Barchilon ve Garamendi tarafından kullanıldığı şekilde dört grupta sınıflandırıldı ve hastalar, yaşlarına göre yedi gruba ayrıldı. Birinci sağ kosta kırırdağının kalsifikasyon derecesi ile hastaların yaşları arasındaki ilişki, Spearman'ın rho katsayısı ile değerlendirildi. **Bulgular:** Birinci kosta kırırdağının kalsifikasyon derecesine göre ortalama yaş; derece 0'da 5,56, derece 1'de 25,49, derece 2'de 45,39 ve derece 3'te 66,02 olarak tespit edildi. Sağ birinci kosta kırırdağının kalsifikasyon derecesi ile kadın ve erkeklerdeki yaş arasında istatistiksel olarak anlamlı düzeyde ilişki mevcut [Spearman'ın rho katsayısı=0,904, $p<0,001$ (erkeklerde 0,924, $p<0,001$ ve kadınlarda 0,864, $p<0,001$)]. **Sonuç:** Yaş grupları arasında bazı çakışan değerler olsa da, birinci kosta kırırdağının kalsifikasyon derecesinin göğüs radyografilerinde değerlendirilmesi, kemik yaşı tayininde faydalı olabilir. Bu yaş tespiti metodu ceza mahkemelerinde ve adli antropolojide yardımcı bir teknik olarak kullanılabilir.

Anahtar Kelimeler: Adli tıp; radyografi; toraks; yaş grupları

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Histologically, bone is a vascular, mineralized connective tissue consisting of cells and an intercellular matrix in which its cells are embedded.¹ The process concerning the conversion of cartilage and connective tissue into bone tissue is called osteogenesis. Since the appearance and fusion of ossification centers follow the same model from birth to adulthood, it is a significant criterion in assessing the bone growth and age. The bone age is determined by radiological examination of the bones of the knee and foot within the first three months of life and the bones of the hand and wrist at older ages. The maturation process of the long bones includes consecutive stages of connective tissue, cartilage development and mineralization (enchondral ossification). The primary ossification centers advance from diaphysis to the bone ends. Following the completion of primary ossification (usually after birth), nuclear ossification (epiphyseal nucleus) begins at the ends of the cartilage bone model. Bones generally have compact and cancellous parts. Compact bone consists of concentric lamellas around the Haversian system. Bone is in a constant state of remodeling. With age, resorption exceeds formation resulting in an overall loss of bone.² The ossification that begins in the epiphysis is called secondary ossification. The sizes and forms of the epiphyses, and their relationship with the diaphyses, are the main parameters in the assessment of the degree of bone maturation and it shows the potential for height growth. At the end of adolescence, when the fusion between the metaphysis and the epiphysis occurs, the process of growth ends (closure of the epiphysis). With advancing age, the long bones become lighter and more brittle due to these changes and to an increase in inorganic constituents.³ Kerley describes the consistent changes in the shafts of long bones with advancing age.⁴

In the forensic medicine, age estimation plays an important role to identify the individual.¹ There are studies showing that environmental factors play a particular role along with sex and race on the development of bones.^{5,6} Certain hormonal factors in men and women may affect ossification.⁷ Therefore, bone age can only be determined ap-

proximately. Although age estimation is used for identification purposes in the developed countries, in Turkey, it is carried out to determine the real age of a person with an already known identity because of inaccurate birth records especially in rural regions. Bone and cartilage are important tissues in determining the age of death in forensic medicine. Bones, even fragments, can be used for age prediction microscopically and provide an approximate age-at death.⁴ One of the other structures studied for this reason is costochondral junction.⁸⁻¹⁰

In this article, we aimed to investigate whether the calcification degree of the first costal cartilage could be used in age determination based on postero-anterior chest x-rays as suggested in previous studies.¹¹⁻¹³

MATERIAL AND METHODS

Postero-anterior chest X-rays of 471 patients (270 males, 201 females) were reviewed retrospectively. Our institutional review board approved this retrospective study. The X-rays belonged to army recruits (assessed routinely by the Department of Radiology), patients requiring preoperative evaluation, and patients from the outpatient clinic visiting the department for diagnostic purposes. The patients were divided into seven groups with regard to age: 0-20, 21-30, 31-40, 41-50, 51-60, 61-70 and >70.

The calcification stages of the right first costal cartilages were examined on postero-anterior chest x-rays based on the stages of calcification used in the study of Barchilon et al. and Garamendi et al.¹¹⁻¹³ Two radiologists reviewed the x-rays concurrently to avoid inter-observer variability. Consistent with previous studies, the left side could not be evaluated. The level of calcification was classified in four stages as follows (Figure 1).

Stage 0: No calcification,

Stage 1: Recent onset of calcification, <50%,

Stage 2: Incomplete but ≥50% calcification,

Stage 3: Almost complete or complete calcification.

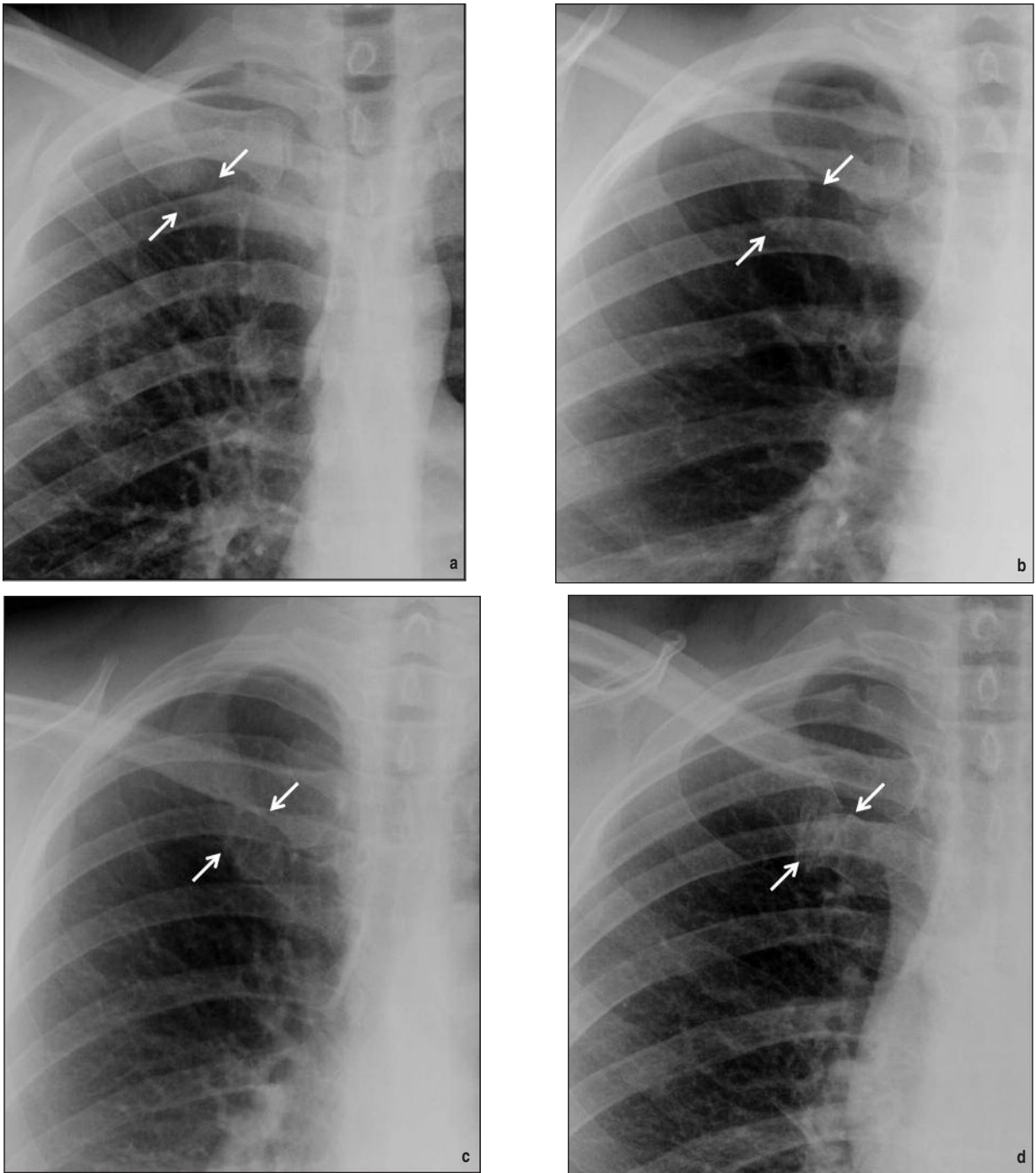


FIGURE 1: Postero-anterior chest x-rays (a-d) show calcification stages of the right first costal cartilage (arrows). Figures (a), (b), (c) and (d) indicate stage 0, 1, 2 and 3 calcification of the costal cartilage, respectively.

Percentage (%) for discrete data and median (minimum-maximum) values for continuous data were used in descriptive statistics. Calcification stages were evaluated according to sex and age. The relationship between age and the level of calcifica-

tion was examined by Spearman's correlation coefficient. All statistical analyses were made by using SPSS release 15.0 program (SPSS for Windows; SPSS, Chicago, IL, USA). P values less than 0.05 were considered significant.

RESULTS

Postero-anterior chest X-rays of 471 [270 (57.3%) male and 201 (42.7%) female] patients were reviewed. Mean age±standard deviation was 42.38±20.69 years (range from 1 to 88 year).

Radiographic examination was performed on 68 patients (47 male, 21 female) in the 0-20 age group, 91 patients (71 male, 20 female) in the 21-30 age group, 74 patients (35 male, 39 female) in the 31-40 age group, 63 patients (32 male, 31 female) in the 41-50 age group, 60 patients (31 male, 29 female) in the 51-60 age group, 72 patients (35 male, 37 female) in the 61-70 age group, and 43 patients (19 male, 24 female) in the >70 age group.

Mean age was 5.56 for stage 0, 25.49 for stage 1, 45.39 for stage 2, 66.02 for stage 3 calcification. In the male and corresponding female age groups, mean calcification and age values were presented in (Table 1).

The relationship between the degree of calcification and age in males, females, and both genders were shown in (Figure 2, 3, Table 2).

Spearman's rho analysis revealed significant positive correlations between the calcification stage of the right first costal cartilage and age groups in males and females [Spearman's rho=0.904, $p<0.001$ ($r=0.924$, $p<0.001$ in males and $r=0.864$, $p<0.001$ in females)].

DISCUSSION

Throughout life, costochondral cartilage of the first rib is among the regions in the human body that undergoes extensive change.¹¹ The first rib carti-

lage is exceptional among all other rib cartilages because it is the first to mineralize and ossify preceding all other rib cartilages, and it is considered remnant done.^{11,14} On the other hand, its osteogenesis shows both intramembranous and enchondral ossification.¹⁴

Some authors such as Barchilon et al., Garamendi et al., King, Semine and Damon, McCormick, Barres et al. made osteological, radiological, and histopathological analyses of the ossification process of the first rib.^{11-13,15-18} They indicated that the calcification of the first rib was a real ossification process. In this process, respiratory stress seems to be the main cause of ossification of the first rib, whereas it is chest expansion in the lower ribs.¹³

In our study, mean ages for calcification were 5.56, 25.49, 45.39 and 66.02 for stage 0, 1, 2 and 3, respectively. In the study of Garamendi et al., mean ages for calcification were 18.03 for stage 0, 28.09 for stage 1, 45.74 for stage 2, 55.56 for stage 3.^{12,13} Garamendi et al. reported stage 0 calcification predominantly in subjects between 5 and 19 years of age and stage 3 and 3 calcification in 24 years old subjects.^{12,13} In our study, stage 0 calcification was present in subjects between 1 and 14 years of age and we had results similar to those of Garamendi et al. for stage 2 and 3 subjects. While the median value for stage 0 was 5.00 years in our study, it was 17.64 years in their study.^{12,13} Our study group included a higher number of pediatric subjects compared to their study and there was a difference in mean ages of stage 0 groups of the two studies due to median values.

TABLE 1: The relationship between the age and calcification degree of the first costal cartilage.

Calcification stage	Number of cases	Mean±SD	Age		
			Median	Minimum	Maximum
Stage 0	34	5.56±3.82	5	1	14
Stage 1	146	25.49±6.33	24	13	43
Stage 2	153	45.39±10.76	45	24	69
Stage 3	138	66.02±8.94	67	40	88
Total	471	42.39±20.69	41	1	88

SD: Standard deviation.

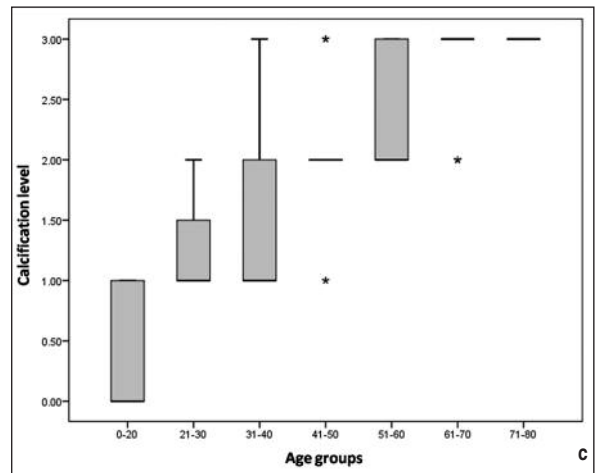
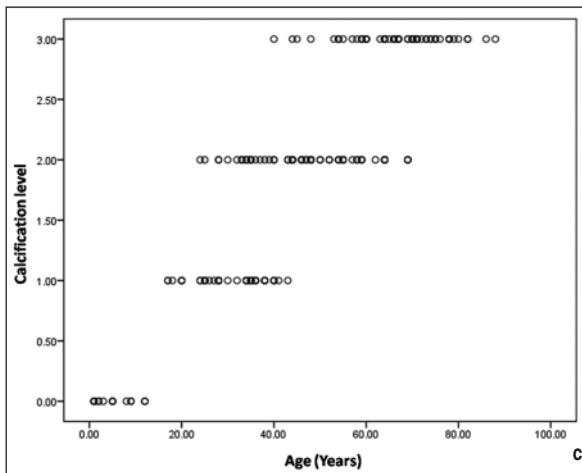
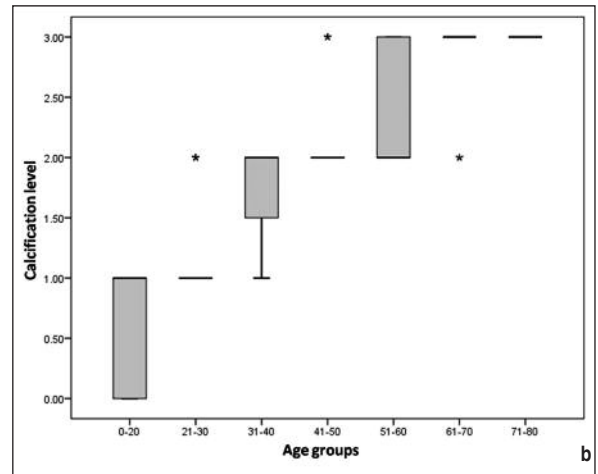
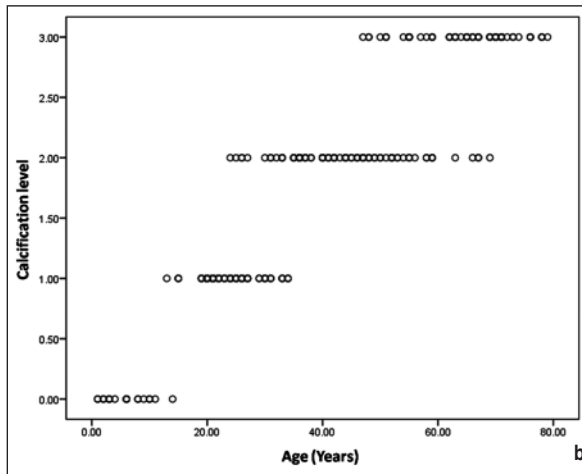
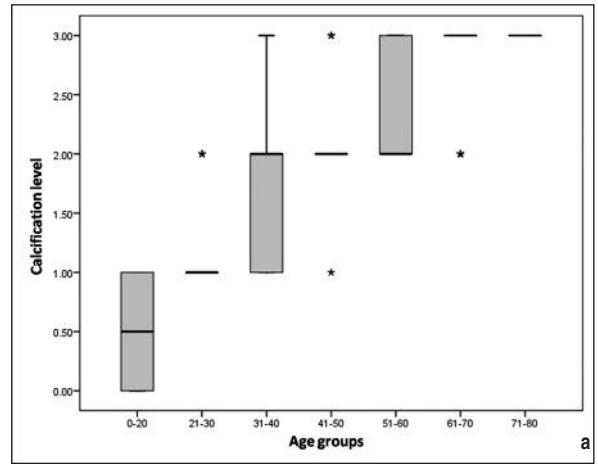
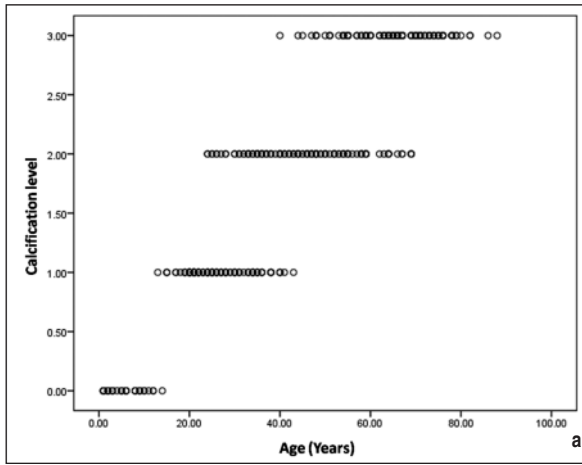


FIGURE 2: Scatter plots show the relationship between the calcification stage of the right first costal cartilage and patient's age (a) in both sexes, (b) in males, and (c) in females.

FIGURE 3: The box-plots show the mean calcification stage of right first costal cartilage in age groups of both genders (a), males (b), and females (c).

Overall Spearman's rho value was 0.904 for the study group. Since the result was very close to "1", the examination of first costal cartilage was

considered eligible for the study. The values for men and women were 0.924 and 0.864, respectively.

TABLE 2: The degree of calcification according to age and sex groups.

Age group	Calcification stage: median (minimum-maximum)		
	Male	Female	Total
0-20	1 (0-1)	0 (0-1)	0 (0-1)
21-30	1 (1-2)	1 (1-2)	1 (1-2)
31-40	2 (1-2)	1 (1-3)	2 (1-3)
41-50	2 (2-3)	2 (1-3)	2 (1-3)
51-60	2 (2-3)	2 (2-3)	2 (2-3)
61-70	3 (2-3)	3 (2-3)	3 (2-3)
71+	3 (3-3)	3 (3-3)	3 (3-3)
Total	2 (0-3)	2 (0-3)	2 (0-3)

In our study, median value for stage 3 calcification was 67.00 years, but in the other study, it was 57.28 years.¹² Therefore, there was a significant difference between the two studies with regard to median values. In our study, overall mean and median age values were 42.39 and 41.00 years, respectively, whereas same values were 44.64 and 45.43 years in the other study.¹² The results obtained in the Turkish population show similarity to those acquired from the other study.¹²

Based on the findings of their study, Garamendi et al. suggested that further research on other populations would be required for age estimation based on the degree of ossification of the first costal cartilage before this test becomes the routine in medico-legal practice.^{12,13} They suggested that the analysis of the ossification degree of the first rib cartilage could be useful as a complementary method for the forensic estimation of age based on radiographic methods.^{12,13}

Barchilon et al. investigated the extent of costochondral ossification in 78 chest X-rays of 13 healthy male soldiers who are subjected to a periodic follow-up.¹¹ In that study including a limited number of subjects and age groups, the authors reported that they were in agreement with McCormick's conclusion and that the degree of ossification of the first costal cartilage, as an indicator of age, did not provide the precision necessary for anthropological or forensic studies.¹⁷ McCormick examined 250 cadavers with soft X-ray in his study

and reported that similar degrees of mineralization over a wide age span during middle ages, seriously limited the value of this method in age estimation.¹⁷ On the other hand, he noted that the ease, rapidity, and relative inexpensiveness were the advantages of this procedure on intact or partially decomposed bodies, especially where an expert physical (forensic) anthropologist was not readily available.

In another study presenting a method for estimating the age at death by quantitating roentgenologic features of X-ray films of chest plates obtained during routine autopsies, Barres et al. indicated that this method allowed estimation of age and could be used in age estimation of an unknown age-at-death individual.¹⁸

The most important limitation of our study was its retrospective design. Besides, it included only postero-anterior chest X-rays. Therefore, the systemic problems such as hyperparathyroidism and hypercalcemia that might affect bone mineral density were not investigated. We believe that there are more specific age estimation methods such as wrist X-rays in 0-20 age groups. In addition, pelvis, lateral sacrum, lateral coccygeus and lateral sternum X-rays can be used as age estimation devices in individuals 20-45 years of age. However, in those aged 50-71+ years, there is no described specific method for age estimation, and our results are promising in that specific age group. For individuals aged 20-71+ years, the skeletal changes are not prominent and last longer than those in people aged 0-20 years. Although the costochondral structure may be used for age estimation among individuals aged 20-71+ years, long duration and uncertainty of the changes, wide age range in the groups and limited number of age groups are the disadvantages of this method.

In Turkey, the state provides some special exemptions and allowances to the elderly. Turkish citizens who are older than 65 years, poor, debilitated or helpless receive payment from the government according to Turkish legislations. Furthermore, some local governments provide special exemptions for people over 58 or 60 years of age, including discounts in public transportation and leisure centers.

People may take advantage of this by attempting to make false statement regarding their ages. We hope that our study will facilitate the workflow of such processes in Turkish courtrooms. We believe that the mean age values that we determined for stage 2 (45.39 years) and stage 3 (66.02 years), will be useful only after a certain age, following closure of the epiphyses in long bones.

CONCLUSION

Although there are overlaps among age groups, the assesment of the calcification degree of the first costal cartilage on chest X-rays may be useful in determining the bone age. This method may be used in criminal courts and forensic anthropology as an additional technique.

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