Research Article / Araştırma Makalesi

Estimation of Gender by Costochondral Calcification Model Obtained from Computed Tomography Image

Bilgisayarlı Tomografi Görüntüsünden Elde Edilen Kostokondral Kalsifikasyon Modeli ile Cinsiyet Tahmini

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Abstract

Background: Gender estimation plays a key role in human identification. Between the various measurement methods of gender estimation from skeletal remains, the use of the calcification patterns of costal cartilages is highly suggested especially when the skull and pelvic bones are not available. The purpose of this study is to determine the patterns of costal cartilage calcifications in the Turkish population and to predict gender accordingly.
Materials and Methods: Our study was performed by using the Computed Tomography (CT) images of 200 individuals (100 female, 100 male) in the 20-60 age group who applied to Karabük University Training and Research Hospital and had no costal pathology or surgery history. The classification of Rejtarova et al. (2004) was used for the patterns of costal cartilage calcifications, and it was calculated the number and percentage of each pattern in male and female to estimate the gender.
Results: The results showed 193 (96.5%) individuals with calcification in the costal cartilages and 7 (3.5%) individuals without calcification in their costal cartilages, which 3 females and 4 males. Peripheral pattern (Type I) showed 100% male gender prediction, while central pattern (Type II) showed female gender prediction with 92.3%. Type III was the most common pattern with 66.8% in the Turkish population.
Conclusions: As a result of this study, costal cartilage calcification models were obtained in the Turkish population using the method of Rejtarova et al (2004). Type I and Type II patterns showed high accuracy in terms of the usability of these models in predicting gender.

Key Words: Computed Tomography, Costal Cartilage, Calcification, Gender Estimation

Öz.

Amaç: Cinsiyet tahmini, insan kimliğinde önemli bir rol oynar. İskelet kalıntılarından cinsiyet tahmininin çeşitli ölçüm yöntemleri arasında, özellikle kafatası ve pelvik kemiklerin bulunmadığı durumlarda, kaburga kıkırdaklarının kalsifikasyon paternlerinin kullanılması şiddetle tavsiye edilir. Bu çalışmanın amacı, Türk popülasyonundaki kostal kıkırdak kalsifikasyonlarının paternlerini belirlemek ve buna göre cinsiyet tahmininde bulunmaktır.
Materyal ve Metod: Çalışmamız Karabük Üniversitesi Eğitim ve Araştırma Hastanesi'ne başvuran 20-60 yaş grubundaki 200 kişinin (100 kadın, 100 erkek) Bilgisayarlı Tomografi (BT) görüntüleri kullanılarak gerçekleştirildi. Rejtarova ve ark. (2004), kostal kıkırdak kalsifikasyonlarının kalıpları için kullanılmış ve cinsiyeti tahmin etmek için kadın ve erkekte her bir kalıbın sayısı ve yüzdesi hesaplanmıştır.
Bulgular: Kostal kıkırdaklarında kalsifikasyon olan 193 (%96,5) birey ve kostal kıkırdaklarında kalsifikasyon olmayan 7 (%3,5) birey olduğu görüldü, bunlardan 3'ü kadın ve 4'ü erkekti. Periferik desen (Tip I) %100 erkek cinsiyet tahmini gösterirken, merkezi desen (Tip II) %92,3 ile kadın cinsiyet tahmini gösterdi. Tip III, Türk popülasyonunda %66,8 ile en sık görülen örüntüydü.
Sonuç: Bu çalışma sonucunda, Rejtarova ve arkadaşlarının (2004) yöntemi kullanılarak Türk popülasyonunda kostal kıkırdak kalsifikasyon modelleri elde edilmiştir. Tip I ve Tip II örüntüleri, bu modellerin cinsiyet tahmininde kullanılabilirliği açısından yüksek doğruluk göstermiştir.

Anahtar kelimeler: Bilgisayarlı Tomografi, Kostal Kıkırdak, Kalsifikasyon, Cinsiyet Tahmini

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Introduction

Human identification is the main topic in forensic anthropology which identifies the skeleton remains of the human body based on the assessment of age, gender, stature, and individual traits (1). Nowadays, the importance of human identification is still one of the most challenging after a natural disaster, war crimes, or terrorist attacks (2). The identification process is not only important for the deceased but also for surviving family and friends or may be required legally, for example, to aid criminal proceedings, facilitate settlement of estate and inheritance, or the right of the remaining partner to re-marry (3).

The new techniques in human identification that are using anthropological data like race, age, stature, and gender are increasing with time because it's more available than DNA technologies which are more expensive and less available (4). Radiology applications have been used in forensic medicine for human identification, especially in cases where the body is fragmented, decomposed, or burned, and the cranium is considered the most helpful region of the body for comparison radiologically (5). The determination of age and gender according to the costal cartilage calcification patterns is well documented (6). In addition to that, it is useful in forensic anthropology, especially when the pelvic bones and skull are not available (7). The difference between male and female in the patterns of costal cartilage calcification was first described by Fischer in 1955 (8). After that, many authors described the difference in their studies (9-11).

The calcification patterns of costal cartilage are separated according to the radiographic appearance into three general categories: a peripheral type, a central type, and a mixed type (9, 12, 13). Rejtarova et al., classified the calcification patterns into four groups: a peripheral pattern, a central pattern, a mixed pattern, and an indifferent pattern. the central type also divided into three further subgroups: central lingual pattern, central globular pattern, and central lingual and globular pattern (14).

According to our literature research, studies on this subject mostly focus on roentgenography, and there are no similar studies conducted on the Turkish population. The aim of our study is to determine the patterns of costal cartilage calcifications and the number and percentage of each pattern in male and female, using CT images with the classification of Rejtarova et al. (14), which was recently reported.

Materials and Methods

This retrospective study was initiated with the approval of the local non-invasive ethics committee dated 31.08.2020 and numbered 321. The study included 200 subjects (100 females, 100 males) age 20-60 years without costal fracture, a history of surgical history, or any

skeletal pathology. The radiology result report of these individuals, who applied to Karabük University Training and Research Hospital with the suspicion of Covid 19 and underwent thoracic Computed Tomography (CT), was normal.

All CT images were transferred from the hospital PACS archive system to the personal workstation, and evaluated using a DICOM viewer (RadiAnt Viewer, Version 2020, Poland) by a radiologist (S.O.) with at least 10 years of experience. Each CT image was studied for looking to at evidence of any calcification in the costal cartilages by seeing the anterior view of the chest and then carefully studied for the patterns of calcification in the costal cartilages. The images were optimized with thickness, color and zoom settings to show the best view of the sternum, costal cartilages and ribs using the 3D MPR tool. After that, the images were saved and labeled with the details of name, age, and gender. All of the costal cartilages are studied except the first costal cartilage which is not show any difference in the calcification patterns between males and females because it differs from the others in the nature of its calcification (15). By using the method of Rejtarova et al. (14), classified the patterns of calcification as follows:

Type I: Peripheral pattern (P), characterized by calcification of the inferior and superior costal cartilage margin (Figure 1).

Type II: Central pattern (C), which is subdivided into three subtypes:

Type IIa: Central lingual pattern (Cl), characterized by pyramidal-shaped central tongues of calcification beginning at the fossae costarum (the fossa at the anterior end of a rib at the union with the costal cartilage).

Type IIb: Central globular pattern (Cg), consisting of centrally placed, smoothly contoured globules of calcification (Figure 2).

Type IIc: Central lingual and globular pattern (Clg) (Figure 3).

Type III: Mixed (peripheral and central pattern) (Mix) (Figure 4).

Type IV: Indifferent pattern (Ind)- incipient calcification without differentiation into a gender-specific pattern (Figure 5).

Microsoft Excel (2010) was used for the analysis, which included making tables, distributing the numbers of cases according to the previously mentioned calcification patterns, and extracting the percentages for them.

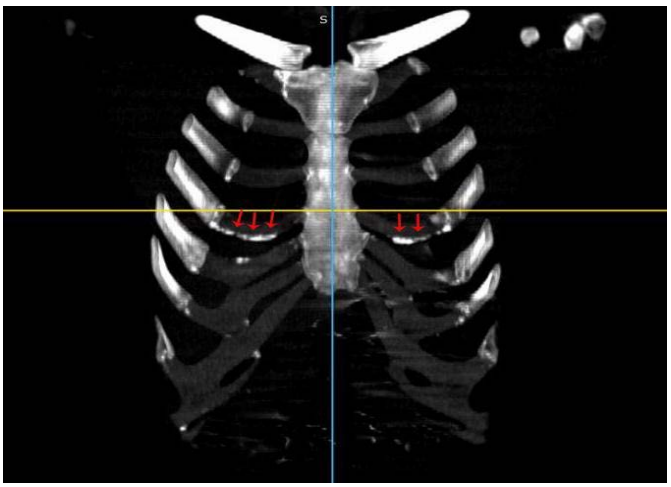

Figure 1. Peripheral pattern of costal cartilage calcification (Type I).

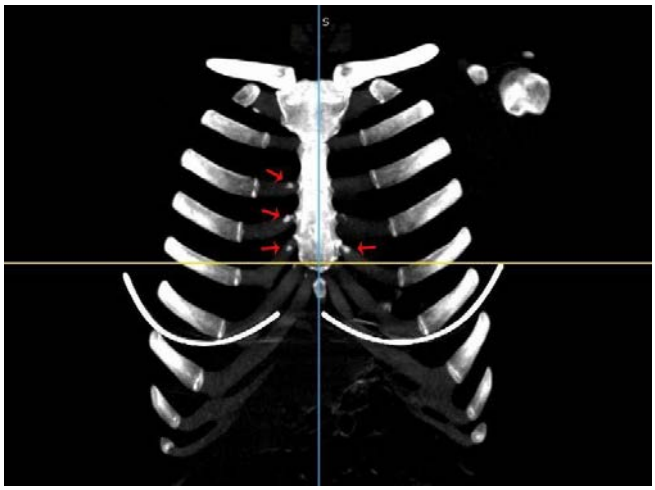

Figure 2. The central globular pattern of costal cartilage calcification (Type IIb).

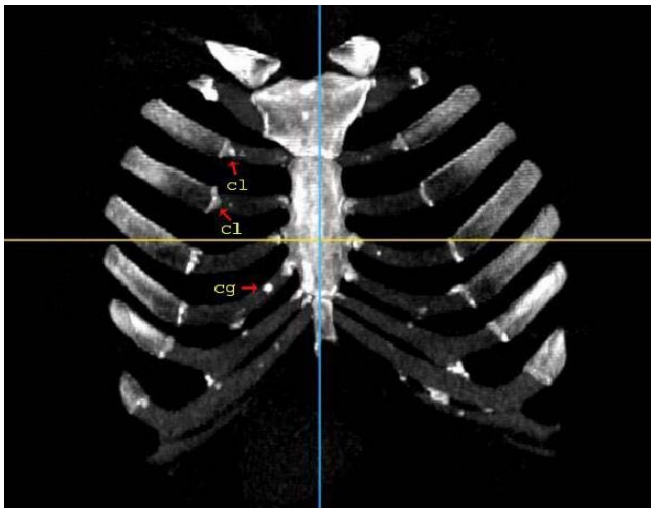

Figure 3. Central lingual (cl) and globular (cg) pattern of costal cartilage calcification (Type IIc).

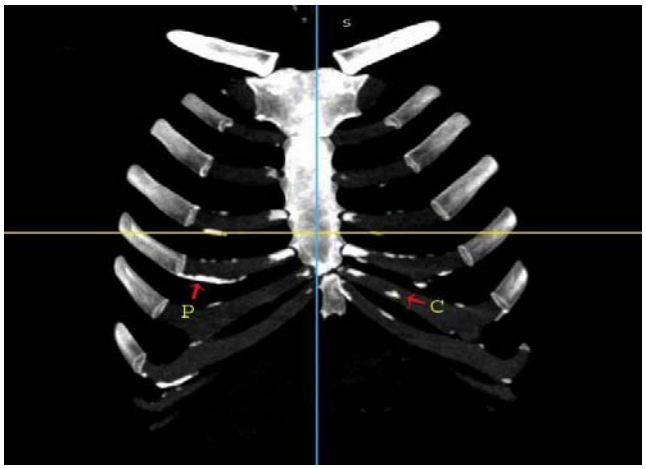

Figure 4. Mixed (peripheral (p) and central (c) pattern) Type III.

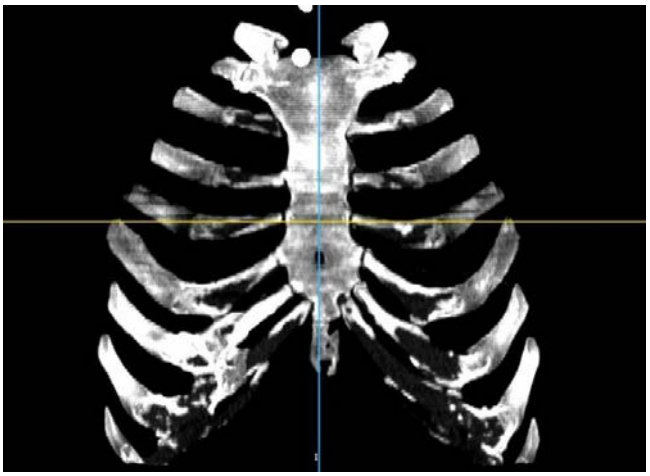

Figure 5. Indifferent pattern of costal cartilage calcification (Type IV).

Results

Our study was applied to 200 individuals (100 females, 100 males) in the 20-60 age group to estimate the gender by calculating the number and percentage of the individuals with each costal cartilage calcification pattern. The mean age of the female was 41.12 ± 10.60, and the mean age of the male was 35.39 ± 9.22. Ages of male and female individuals were tested with the Anderson Darling test, which is a normality test, and it was found that they did not show normal distribution. With the Mann-Whitney U test, a significant difference was found between males and females according to age ($p \leq 0.05$) (Table 1).

The results showed the number of individuals with costal cartilage calcification was 193, in which 97 females and 96 males, while found only 7 individuals without any calcification in their costal cartilages, in which 3 females and 4 males (Table 2).

Table 1. The mean age of female and male.

Gender	Median	Minimum	Maximum	P Value*
Female	39.00	20	60	**0.0001**
Male	34.50	20	60	

**Mann-Whitney U Test*

Table 2. Number of individuals with costal cartilage calcification in female and male.

Gender	Negative	Positive	Total
Female	3	97	100
Male	4	96	100
Total	7	193	200

Positive: with calcification, Negative: without calcification

The percentage of individuals with costal cartilage calcification was 96.5%, while found 3.5% of individuals without calcification (Figure 6).

The results showed the number of individuals with peripheral pattern (Type I) was 6 males, while not found the peripheral pattern in females. The number of individuals with central pattern (Type II) was 39, in which 36 females and 3 males.

The number of individuals with mixed pattern (Type III) was 129, in which 46 females and 83 males. The number of individuals with indifferent pattern (Type IV) was 19, in which 15 females and 4 males (Table 3).

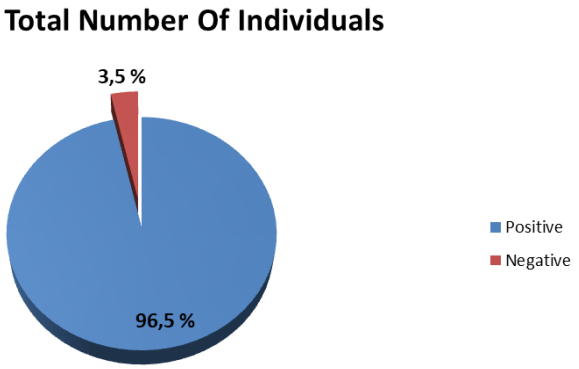

Figure 6. Percentage of individuals with costal cartilage calcification (Positive: with calcification, Negative: without calcification)

Table 3. Number of of each costal cartilage calcification pattern in female and male.

Gender	P Type I	C Type II	Mix Type III	Ind Type IV	Total
Female	0	36	46	15	97
Male	6	3	83	4	96
Total	6	39	129	19	193

P: peripheral pattern, C: central pattern, Mix: mixed pattern, Ind: indifferent pattern.

The percentage of the individuals with peripheral pattern (Type I) was 100% in males and 0% in females. The percentage of individuals with central pattern (Type II) was 92.3% in females and 7.7% in males. The percentage of individuals with mixed pattern (Type III) was 35.7% in females and 64.3% in males. The percentage of individuals with indifferent pattern (Type IV) was 78.9% in females and 21.1% in males (Figure 7).

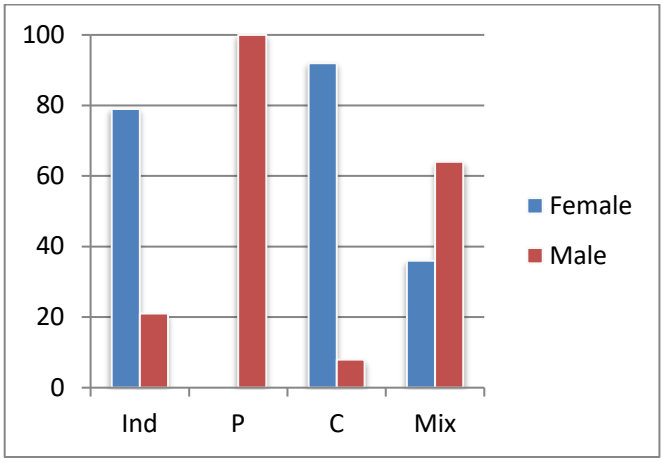

Figure 7. Percentage of each costal cartilage calcification pattern in female and male (Ind: indifferent pattern, P: peripheral pattern, C: central pattern, Mix: mixed pattern).

The results showed the number of individuals with central globular pattern (Type IIb) was 14, in which 13 females and 1 male. The number of individuals with central lingual and globular pattern (Type IIc) was 25, in which 23 females and 2 males. No central lingual pattern (Type IIa) was found in males and females (Table 4).

Table 4. Number of each central pattern subtype in female and male.

Gender	Cl Type IIa	Cg Type IIb	Clg Type IIc	Total
Female	0	13	23	36
Male	0	1	2	3
Total	0	14	25	39

Cl: central lingual pattern, Cg: central globular pattern, Clg: central lingual and globular pattern.

The percentage of individuals with central globular pattern (Type IIb) was 92.9% in females and 7.1% in males. The percentage of individuals with central lingual and globular pattern (Type IIc) was 92% in females and 8% in males. While the percentage of central the lingual pattern (Type IIa) was 0% in males and females (Figure 8).

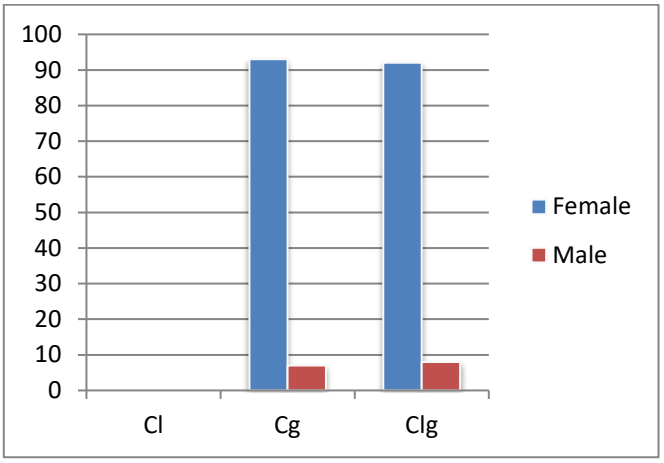

Figure 8. Percentage of each central pattern subtype in female and male (Cl: central lingual pattern, Cg: central globular pattern, Clg: central lingual and globular pattern).

Discussion

The results of this study, which we planned to discriminate according to costochondral calcification patterns, showed that the Type I pattern predicts 100% of the male gender and the Type II pattern predicts the female gender at the rate of 92.3%. The most common pattern in the Turkish population is Type III, which is a mixed type with a rate of 66.8%. No costal cartilage calcification was observed in 3.5%.

Gender estimation represents one of the most important components of the biological identity that used in the traditional techniques for human identification from skeletal remains (16). Between various methods for estimation gender, the radiological study of costal cartilage calcification pattern is a simple, rapid, and inexpensive method, requiring little expertise. It could best method for the estimation of the gender

in all cases requiring gender establishment in the living or in the dead, provided the thoracic cage is intact (17).

According to our literature research there are few roentgenography studies to determine costal cartilage calcification patterns in gender estimation (18). However, the roentgenography technique is disadvantageous in image processing as it is two-dimensional, superposition and dependent on user experience. The use of CT in postmortem imaging has increased in recent years. CT is more advantageous in that it is three-dimensional, allows image processing, and offers the most realistic image. In our study, we think that we have achieved very high success in estimating the gender by determining the costochondral calcification patterns in the Turkish population by taking advantage of these advantages of CT.

Previous studies have used the difference in the calcification patterns that appeared in the costal cartilage for gender estimation, like the study that applied to the Czech population in (14) and take 1044 chest and abdominal radiograms from the Department of Radiology, Charles University Hospital in Hradec Králové in the period (1995–2003), with age ranging from 10 to 95 years and included 537 male and 507 female. In this study, the first costal cartilage was ignored and used a method that classifies the patterns of calcification into main four groups (peripheral pattern, central pattern, mixed pattern, and indifferent pattern), and subdivided the central group into three further subgroups (central lingual pattern, central globular pattern, central lingual and globular pattern). The result of this study found calcification of the costal cartilage in 528 (51%) individuals and not found any calcification in 516 (49%) individuals. In this study, in which we used the same classification, no costochondral calcification was found to a lesser extent (3.5%). We think that the rate of absence of costochondral calcification is high due to the inclusion of the younger age group in the study of Rejtarova et al. This shows that costochondral calcification patterns are difficult to use for sex prediction at early ages.

In the same study, the incidence of Type I pattern was 47.3%, and the success of estimating male gender was reported as 99.6% (14). In our study, the incidence of Type I pattern was 3.1%, and the success of predicting male gender was found to be 100%. The reason for the low incidence of Type I pattern in this study may be due to age, a number of patients, and population differences. In both studies, Type I pattern was found to have a high accuracy rate in determining male gender.

According to Rejtarova et al. (14) reported Type II pattern as 38.1% in their study and obtained a 100% female gender estimation. In this study, the rate of Type II pattern was 20.2%, and 92.3% of this pattern showed female gender. All the subtypes of central pattern found in the previous study as the following: central lingual pattern (Type IIa) found in 114 (57%) individuals, central globular pattern (Type IIb) found in 47 (23%) individuals, central lingual and globular pattern (Type IIc) found in 40 (20%) individuals. In this study, Type IIb was found to be 14 (36%) and Type IIc 25 (64%), although Type IIa was not found at all. Although there are differences between Type II subgroups in this respect, it has been shown that the Type II pattern has high accuracy in showing female gender.

According to the previous study, in which we took the classification as an example, Type III and Type IV patterns were reported as 5.1% and 9.5%, respectively. While the female sex ratio was 85.2% in the Type III pattern, it was 70% in the Type IV pattern (14). In our population, Type III pattern was the most common pattern with a rate of 66.8%. Type IV pattern was found in 9.8%. The male gender prediction rate was 64.3% in the Type III pattern, while it was 78.9% for female gender in the Type IV pattern. The results of both studies show that Type III and Type IV patterns give less accurate gender prediction than Type I and II.

The other study that applied to the Scottish population and took 41 chest radiographs from the Laboratory of Human Anatomy, University of Glasgow, between 2006 and 2010, included 19 females and 22 males, with ages ranging from 67–91 years for female and 57–91 years for male (19). This study used the method of Rejtarova et al. (14), to classify the calcification patterns of costal cartilages and found 22 individuals (53.7%) in which the gender indeterminate and 19 individuals wherein theory gender could be determined, 11 (57.9%) were correctly identified as female while 8 (42.1%) were males wrongly identified as females. According to Middleham et al., it was reported that gender estimation based on costochondral calcification patterns did not give good results in the Scottish population. In comparison with our study, we found 148 (76.7%) individuals in which the genderwas indeterminate and 45 (23.3%) individuals wherein theory gender could be determined, 6 were correctly identified as male and 36 correctly identified as female, while 3 were males wrongly identified as females. In the other words, our results were more accurate in the estimation of gender than the previous study because from the total number of individuals (45) wherein theory gender could be determined, 42 individuals were correctly identified, 36 individuals as female, and 6 individuals as male. While in the previous study from the total number of individuals (19) wherein theory gender could be determined, just 11 individuals were correctly identified as female.

In conclusion, the rate of calcification in the costal cartilages was 96.5% in our population, and Type III was the most common pattern. According to Rejtarova et al. classification, Type I and Type II patterns make a high-accuracy estimation of gender (100% male, 92.3% female, respectively). Type III and Type IV patterns have lower success in estimating gender (64.3% male and 78.9% female, respectively). However, racial differences must be taken into account in the evaluation of costochondral calcification patterns. In the Turkish population, Type I and Type II costochondral calcification patterns provide high-accuracy estimation of gender, although they are less common (23%) compared to other patterns.

Ethical Approval: *This retrospective study was initiated with the approval of the non-interventional local ethics committee of Karabük University, dated 31.08.2020 and numbered 321.*

Author Contributions:
Concept: A.A., Z.O., S.O.
Literature Review: A.A.
Design : A.A., Z.O., S.O.
Data acquisition: A.A., S.O.
Analysis and interpretation: A.A. S.O.
Writing manuscript: A.A., Z.O., S.O.
Critical revision of manuscript: A.A., Z.O.
Conflict of Interest: *The authors have no conflicts of interest to declare.*
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References

1. Reppien K, Sejrsen B, Lynnerup N. Evaluation of post-mortem estimated dental age versus real age: a retrospective 21-year survey. Forensic science international. 2006;159:S84-S8.
2. Giurazza F, Schena E, Del Vescovo R, Cazzato RL, Mortato L, Saccomandi P, et al., editors. Sex determination from scapular length measurements by CT scans images in a Caucasian population. 2013 35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC); 2013: IEEE.
3. Blau S, Hill A. Disaster victim identification: A review. Minerva. 2009;129.
4. Baraybar JP. When DNA is not available, can we still identify people? Recommendations for best practice. Journal of Forensic Sciences. 2008;53(3):533-40.
5. Sidhu R, Chandra S, Devi P, Taneja N, Sah K, Kaur N. Forensic importance of maxillary sinus in gender determination: A morphometric analysis from Western Uttar Pradesh, India. European Journal of General Dentistry. 2014;3(01):53-6.
6. Stewart JH, Mccormick WF. A sex-and age-limited ossification pattern in human costal cartilages. American journal of clinical pathology. 1984;81(6):765-9.
7. Scheuer L. Application of osteology to forensic medicine. Clinical Anatomy: The Official Journal of the American Association of Clinical Anatomists and the British Association of Clinical Anatomists. 2002;15(4):297-312.
8. Fischer E, editor Verkalkungsformen der rippenknorpel. RöFo-Fortschritte auf dem Gebiet der Röntgenstrahlen und der bildgebenden Verfahren; 1955: © Georg Thieme Verlag KG Stuttgart· New York.
9. Nıshıno K. Studies on the human rib-cartilage. Kekkaku (Tuberculosis). 1969;44(4):131-7.
10. 1Verma G, Hiran S. Sex determination by costal cartilage calcification. Ind J Rad. 1980;34:22-5.
11. Elkeles A. Sex differences in the calcification of the costal cartilages. Journal of the American Geriatrics Society. 1966;14(5):456-62.
12. Navani S, Shah JR, Levy PS. Determination of sex by costal cartilage calcification. The American journal of roentgenology, radium therapy, and nuclear medicine. 1970;108(4):771-4.
13. Gupta D, Mathur A. Influence of sex on patterns of costal cartilage calcification. The Indian journal of chest diseases & allied sciences. 1978;20(3):130-4.
14. Rejtarová O, Slizova D, Smoranc P, Rejtar P, Bukac J. Costal cartilages—a clue for determination of sex. Biomed Pap Med Fac Univ Palacky Olomouc Czech Repub. 2004;148(2):241-3.
15. Kampen WU, Claassen H, Kirsch T. Mineralization and osteogenesis in the human first rib cartilage. Annals of anatomy= Anatomischer Anzeiger: official organ of the Anatomische Gesellschaft. 1995;177(2):171-7.
16. Vacca E, Di Vella G. Metric characterization of the human coxal bone on a recent Italian sample and multivariate discriminant analysis to determine sex. Forensic science international. 2012;222(1-3):401. e1-. e9.
17. Rao NG, Pai LM. Costal cartilage calcification pattern—a clue for establishing sex identity. Forensic Science International. 1988;38(3-4):193-202.
18. Ikeda T. Estimating Age at Death Based on Costal Cartilage Calcification. Tohoku J Exp Med. 2017;243(4):237-46.
19. Middleham HP, Boyd LE, Mcdonald SW. Sex determination from calcification of costal cartilages in a S cottish sample. Clinical Anatomy. 2015;28(7):888-95.