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RESEARCH ARTICLE

Gender Estimation in Anatolian Population from Scapula Measurements Using Volume Rendering Technique with 3D Computerized Tomography

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Abstract:

Objective: The present study aims to evaluate the sexual dimorphism of the scapula and to measure the accuracy of the results of the measurements performed by computed tomography imaging of the thorax for gender estimation in the modern Anatolian population.

Materials and Methods: Multidetector CT images of 302 cases (164 males, 138 females) with ages between 20 and 93 and taken between February 2019 and April 2019 in Radiology Department at Muğla Sıtkı Koçman University Training and Research Hospital were used in this study. Longitudinal lengths (LL), transverse lengths (TL) and scapular spine lengths (SSL) of the right and left side scapulae were measured and evaluated. The effects of measurements on gender determination were determined using Logistic Regression analysis.

Results: Scapula measurements were higher in males than in females ($p < 0.001$). Statistically significant difference was found between transverse lengths of the right and left scapula in females and statistically significant differences in all three measurements in males. The longitudinal, transverse and scapular spine lengths of the scapula were found to be statistically significant when the measurements were used for gender determination. Accordingly, it was seen that longitudinal length of right scapula was the highest accuracy rate.

Conclusion: This study shows that scapula bone is an important bone in sex prediction in the Anatolian population. Therefore, if skull, long bones and pelvic bones cannot be found in forensic medicine and anthropological studies, scapula can be used alone or in combination with other skeletal elements for sex estimation methods.

Keywords: Forensic Anthropology; Sex Estimation; Scapula; Multidetector Computed Tomography; Sexual Dimorphism

Öz:

Amaç: Bu çalışmanın amacı, skapulanın seksüel dimorfizmini değerlendirmek ve toraks bilgisayarlı tomografi görüntüleme yöntemi ile yapılan ölçüm sonuçlarının, modern Anadolu popülasyonunda cinsiyet tayini için doğruluğunu ölçmektir.

Gereç ve Yöntem: Muğla Sıtkı Koçman Üniversitesi Eğitim ve Araştırma Hastanesi Radyoloji Anabilim Dalı'nda Şubat 2019 ve Nisan 2019 tarihleri arasında çekilmiş olan, 20-93 yaşları arasında, 302 vakanın (164 erkek,138 kadın) Multidedektör BT görüntüleri kullanıldı. Sağ ve sol taraf skapulaların longitudinal uzunlukları (LU), transvers uzunlukları (TU) ve spina skapula uzunlukları (SSU) ölçüldü ve değerlendirildi. Ölçümlerin cinsiyeti belirlemedeki etkisi Lojistik Regresyon analizi ile saptandı.

Bulgular: Erkeklerde skapula ölçümlerinin kadınlara göre daha yüksek olduğu görüldü ($p<0.001$). Kadınlarda sağ ve sol skapula transvers uzunlukları arasında istatistiksel olarak anlamlı fark saptanırken, erkeklerde her 3 ölçüm için de istatistiksel olarak anlamlı fark saptandı. Ölçümler cinsiyet belirleme için kullanıldığında skapula longitudinal, transvers ve spina skapula uzunlukları birbirinden bağımsız olarak, istatistiksel olarak anlamlı bulundu. Buna göre en yüksek doğruluk oranını sağ skapula longitudinal uzunluğunun verdiği görüldü.

Sonuç: Bu çalışma Anadolu toplumunda skapula kemiğinin cinsiyet tahmininde önemli bir kemik olduğunu göstermektedir. Dolayısıyla adli tıpta ve adli antropolojide kafatası, uzun kemikler ve pelvis kemiği bulunamadığı takdirde diğer cinsiyet tahmini metotlarıyla veya tek başına kullanılabilir.

Anahtar Kelimeler: Adli Antropoloji; Cinsiyet Tahmini; Skapula; Multidedektör Bilgisayarlı Tomografi; Cinsiyet Dimorfizmi.

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Ethical Declaration
The principles outlined in the Declaration of Helsinki were followed in our study.
* This article is English version of the manuscript entitled as "3 Boyutlu Bilgisayarlı Tomografi ile Volüm Rendering Tekniği Kullanarak Skapula Ölçümlerinden Anadolu Popülasyonunda Cinsiyet Tahmini".

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1. Introduction

Biological identity determination becomes more important in situations, such as disasters, attacks and wars, which may cause mass death or in cases where body integrity is impaired. In such cases, forensic researchers try to identify the four main elements of biological identity, such as gender, age, ethnicity, and height (1). These biological features can be determined from a skeleton even years after death (2,3). Accurate gender prediction based on measurements in human bone remains one of the most important steps in identification (4–6). In particular, the pelvis and skull are considered to be the most useful skeletal sites for gender prediction (1,4–7). Since the morphological features of the pelvis and skull bones show sexual dimorphism, many other bones in the skeleton also show sexual dimorphism, as well as being the most used elements in gender prediction (4). When Krogman and Iscan rank the bones according to the most accurate result in determining gender from skeletal elements, the pelvis 95%, the skull 92%, the mandible 90%, and the long bones (humerus and femur) were 80% accurate (8). When previous studies are examined, it can be found that humerus (9–12), ulna (10–13), radius (10–12), femur (10,12,14–16), tibia (10–12,17,18), patella (19,20), clavicle (21), costa (22), talus (4), calcaneus (23,24), metatarsals (25) and scapula (1,4,5,21,26–30) bones has been studied to investigate their usefulness in gender prediction. The scapulas, on the other hand, have been used in studies because of the negligible morphological changes that develop after completing ossification in addition to being short, flat and better protected than long bones (31–34).

Gender determination can be made from the body or skeletal remains obtained for identification using radiological imaging methods. Making morphometric measurements on bones using radiological methods is preferred because it does not require cleaning, does not damage the bone, and it is more practical and feasible than many other identification methods. Multidetector Computed Tomography (MDCT), which is one of these methods, is frequently used because it is easy to apply and allows marking anatomical structures more accurately.

3D images of the bones can be produced quickly in the MDCT method. Thus, population-specific data are easily collected, making it easier to estimate biological profiles in the skeleton, including gender (5,6). Based on morphometric measurements of the scapula bone measured from CT images, it has been reported that gender estimation can be made in the Chinese (2), Japanese (29), Egyptian (30) and Italian (34) populations. However, since the method determined for a population can only be applied to the populations belonging to the same ethnic group, different formulas are required for different populations (30). When identification studies and gender determination from human bones were scanned in the Anatolian population, it was observed that studies related to the scapula were few and have been mostly conducted on dry bones, which remained under-researched. Considering the diversity of Anatolia's studies on dry bones, it will be difficult to say that it belongs to a certain population. Thus, in our study, we used MDCT images to obtain today's data and to make the most accurate scapula measurements.

In this study, we aimed to determine the relationship between scapula measurements and gender and to investigate the usability of scapula measures in gender determination in the Anatolian population using a three-dimensional volume rendering technique.

2. Materials and methods

Multidetector CT images of 302 cases (164 males, 138 females) between the ages of 20-93, taken between February 2019 and April 2019 in the Department of Radiology at Muğla Sıtkı Koçman University Training and Research Hospital in Turkey were used. Cases with the tumor, trauma, congenital abnormalities that disrupted the integrity of the scapula, or cases who did not complete their ossification were excluded from this study.

Thorax CT images were obtained with a 256-slice multidetector computed tomography device (Siemens, Somatom Definition Flash, Germany). The shooting was done with 1 mm cross-section thickness, 1 pitch, 100 Kv and 70 mAs. The images were processed after they were transferred to the workstation (Syngo CT 2017). 3D reconstructed images were used for evaluation with the volume rendering technique. All measurements on both sides were measured by two observers, respectively. Averages of measurement values were used for statistical analysis. The following osteometric measurements were taken from the scapula (Table 1, Figure 1).

Table 1. Definitions of osteometric measurements		
Measurement	Definition	Reference
Longitudinal length of the right and left scapula (RLL and LLL)	the distance between the upper edge of the processus coracoideus and the angulus inferior in the scapula	(2,30)
Transverse length of the right and left scapula (RTL and LTL)	The distance between the medial edge of the scapula on the spinous axis and the lower edge of the cavitas glenoidalis	(2,30)
The length of right and left scapular spine (RSSL and LSSL)	The distance between the medial edge of the scapula on the spinous axis and the most protruding point of the scapular spine in the lateral	(26,29)

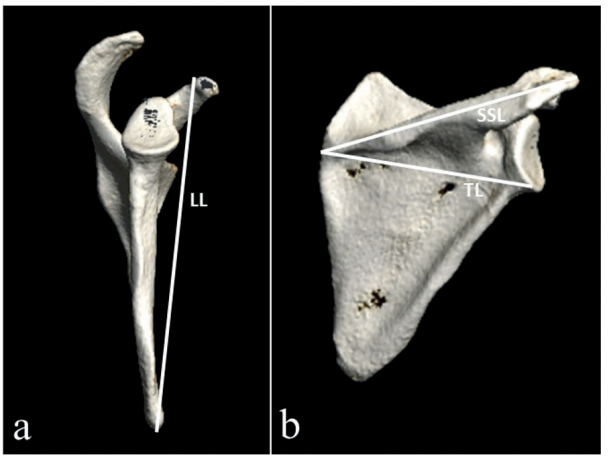

Figure 1. CT scan with volume rendering reconstruction: (a) right scapula, lateral view. LL: Longitudinal length of the scapula (b) right scapula, posterior view. TL: transverse length of the scapula. SSL: length of the scapular spine.

R program was used for the statistical analysis. Metric measurements were given in millimeters. Descriptive statistics were given as mean and standard deviation. Whether there was a statistically significant difference between the right and left sides in the osteometric measurements of the scapula was made by Paired t-test, and comparisons between men and women were made by the Welch t-test. The effects of these measurements on gender determination were determined using Logistic Regression. The sensitivity and specificity of the cut-off values determined by the ROC analysis were calculated according to the Youden method (the point with the highest total of sensitivity and specificity). Results with a P-value of less than 0.05 were considered statistically significant.

Ethical Declaration

The principles outlined in the Declaration of Helsinki were followed in our study.

3. Results

In our study, values of 302 cases, 138 women (45.7%) and 164 men (54.3%) between the ages of 20-93, were used. The average age was 60.47 ± 14.43 years. The average age of women was 58.70 ± 14.63 years, and men were 61.96 ± 14.12 years. No statistically significant difference in age was found between men and women (p=0.051, Welch t-test).

When scapula measurements were evaluated, it was observed that men were higher than women (p <0.001). Descriptive statistical values for all variables in both genders were given in Table 2.

Right and left scapular sizes were compared among women. Accordingly, a statistically significant difference was found between the right and left of the transvers scapular length (p = 0.016, Paired t-test). When the longitudinal length of the scapula and length of the scapular spine were evaluated, no statistically significant difference was found between the right and left scapula (p> 0.05, Paired t-test).

Statistically significant difference was found between the right and left for all three measurements among men (longitudinal scapular lengths, p = 0.0007; transvers scapular length, p = 0.001; lengths of scapular spine, p <0.0001, Paired t-test).

Table 2. Descriptive statistics for all variables of both genders								
	Female (n=138)			Male (n=164)				
	Minimum	Maximum	Mean ± SD	Minimum	Maximum	Mean ± SD	t value	p-value
Age	20	88	58,70 ±14,63	21	93	61,96 ±14,12		
RLL	124,57	189,41	159,81 ±10,77	148,88	206,95	182,36 ±9,51	-19,313	<0.001
LLL	115,97	187,18	159,42 ±10,48	151,69	209,16	183,35 ±9,68	-20,607	<0.001
RTL	89,37	114,97	101,33 ±5,28	96,34	127,74	112,90 ±5,28	-18,989	<0.001
LTL	88,59	117,25	101,91 ±5,51	95,16	128,51	114,55 ±5,91	-19,081	<0.001
RSSL	106,88	149,68	126,72 ±7,82	122,41	158,21	141,61±7,35	-17,037	<0.001
LSSL	107,09	149,68	126,75 ±7,86	125,22	159,58	142,46 ±7,57	-17,652	<0.001

Descriptive statistics were given in mm as mean ± standard deviation. P-values were obtained by the Welch t-test. RLL: Longitudinal length of the right scapula; LLL: Longitudinal length of the left scapula; RTL: Transverse length of the right scapula; LTL: Transverse length of the left scapula; RSSL: The length of right scapular spine; LSSL: The length of left scapular spine.

The cut-off values that can be used to determine gender and the sensitivity and specificity of these values are given in Table 3. These cut-off values, which were determined by ROC analysis, are the levels with the highest total sensitivity and specificity (Youden method). The high AUC values presented in Figure 2-4 show that each of the osteometric measurements evaluated in this study is "independent determinant factors" in gender estimation.

Table 3. ROC Analysis				
		Cut-off value (mm)	Sensitivity	Specificity
Longitudinal length of the scapula	Left	171	91%	92%
	Right	169	93%	84%
Transverse length of the scapula	Left	110	84%	91%
	Right	109	80%	93%
Length of the scapular spine	Left	136	81%	90%
	Right	135	82%	88%

Cut-off values were determined by ROC analysis. The sensitivity and specificity of these cut-off values were calculated according to the Youden method.

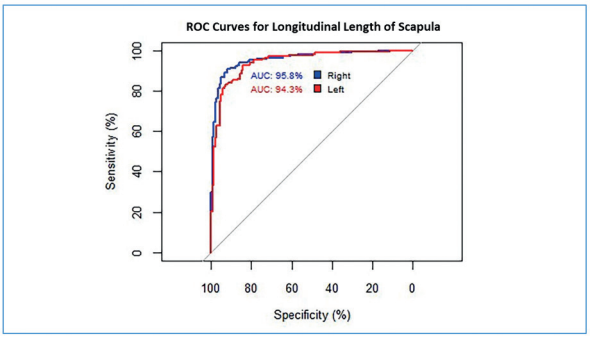

Figure 2. ROC curves and AUC values of longitudinal length of the right and left scapula

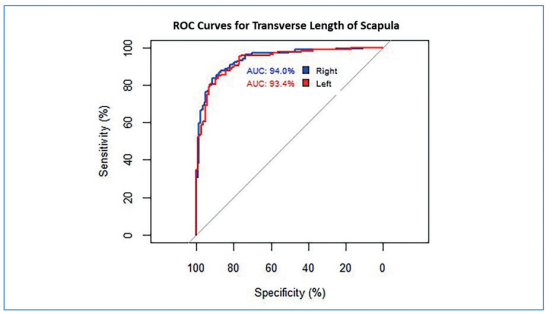

Figure 3. ROC curves and AUC values of the transverse length of right and left scapula

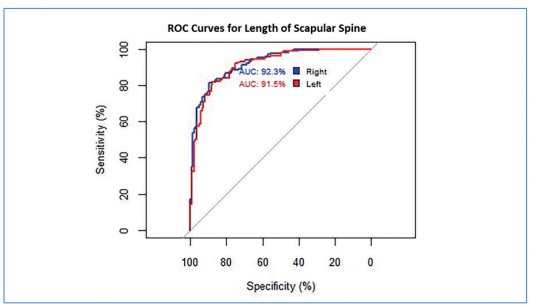

Figure 4. FROC curves and AUC values of length of right and left scapular spine

These cut-off values can be interpreted as follows. The percentage of the correct male identification was 91% when the left longitudinal scapular length (LLL) was longer than 171 mm. However, the percentage of correctly defined women was 92% who had shorter LLL than 171 mm and the rate of misidentification was 8% (false positive).

In other words, for unknown genders, the prediction that the left scapula bone with a longitudinal length over 171 mm belonged to a male was 91% correct. Likewise, the prediction that the left scapula bone with a longitudinal length shorter than 171 mm belongs to a female was 92% correct and 8% wrong, statistically.

4. Discussion

Gender distinction, which is very important in identification in forensic medicine and forensic anthropology, is possible with morphometric analysis (35). Radiological examinations after death provide ease of access to morphometric information (36). Using computed tomography, which is one of the most frequently used radiological methods today, morphometric analysis of living individuals is performed non-invasively, with the convenience of accumulating the data of a certain population.

In this study, the osteometric measurements of the scapula were obtained by evaluating the CT images. In our study, the longitudinal and transverse length of the scapula that were measured for each scapula and the length of the scapular spine were found higher in males than in females. In addition, based on the measurement values of the scapula, evaluations were made to estimate the gender of people in the Anatolian population. The results of our study showed that any of the three osteometric measurements we take could be statistically used for gender prediction.

El Dine and Hassan evaluated the changes in scapula width, height and length of scapular spine with age at different genders (37). Accordingly, although the length of scapula was longer in women under six years of age, there was no significant difference. Although measurements in both genders were very close to each other between the ages of 6-12, it was found to be higher in men. Their findings showed that there was a significant difference between genders over 12 years of age. Among the parameters in our study, the mean scapula height was found higher in men than in other studies (2.28,30) (Table 2). These results show that there are structural differences in the scapula between populations. As bone growth is influenced by genetic and environmental factors, and data or formulas about bone measurements among a population are specific to that population. Scapular measurements have been reported to be useful in gender determination in many studies using scapular measurements in different populations. Paulis and Abu Samra (30) reported that the longitudinal length of the scapula could be used to estimate the gender with an accuracy rate of 89% in their study by evaluating the CT images of in the Egyptian population. Zhang et al. (2) found this rate as 84.8% according to the data of the Chinese population in their study. Torimitsu et al. reported that the length of the right and left scapula was more than 90% accurate in predicting gender in the Japanese population (29). Özer et al. found that the accuracy rate of the scapula to be 82.9% in estimating the gender according to the data obtained from skeletal remains in the Dilkaya archeology area of Van region (5). The results of our study showed that if we determine the cut-off value for the longitudinal length of right side scapula as 169 mm in the modern Anatolian population, the sensitivity is 93%, and the specificity is 84%. These results suggest that the longitudinal length of the scapula shows the best sexual dimorphism among the measurements we have taken.

It has been reported that the transverse length of the scapula is longer in females under four years of age and significantly longer in males over 16 years of age (37). Our findings showed that the mean transverse length of the right scapula was 113 mm in males and 101 mm in females, while these values were 115 mm in men and 102 mm in women for the left scapula. These results were consistent with previous studies (2,28,30). In adults, the accu-

racy of the transverse length of the scapula alone in gender estimation was reported as 83%, 86-87%, 91%, respectively, by Zhang et al. (2), Torimitsu et al. (29) and Paulis and Abu Samra (30). In our study, if we determined the cut-off value for the transverse length of the left scapula as 110 mm, the sensitivity was 84% and the specificity was 91%. Debnath et al. found that the scapula width gave the highest accuracy rate among all measurements, such as the height, width, and oblique length of the scapula among the Dakshina Canada population data (28). Özer et al. found that scapular width was the most useful parameter in determining gender when compared with scapular length, width, length of the glenoid cavity and width in their study among skeletal remains (5). In our study, we found that the longitudinal length of the scapula ranks first for the accuracy rate. Each population has its own specific signs of dimorphism. Thus, since the data obtained for gender determination are specific to that population, population-specific formulas should be created and kept up to date.

The length of the scapular spine was found significantly longer in women under two years of age. The growth rate of scapular spine maximizes in males between the ages of 14-19 (37). Our findings showed that the mean value of the length of scapular spine was 142 mm in men and 126 mm in women both on the right and left scapula. These results were consistent with previous studies (27,29). Torimitsu et al. reported the accuracy rate as 87% in adults. (29). According to their study on dry bones, Papaioannou et al. found this rate as 91% (27). In our study, if we determined the cut-off value as 135 mm for the length of the right scapular spine, the sensitivity was 82% and the specificity was 88% (Table 3).

In conclusion, this is a radiological study showing that morphometric analysis of the scapula bone is important for gender determination and can be used as an alternative in forensic anthropology only in cases where measurement can only be taken from the scapula. As osteometric measurement analysis can be performed directly on skeletal remnants, CT can be easily used for this purpose because it can provide a three-dimensional image. However, the accuracy of any method decreases when applied to another population. Therefore, population-specific measurements are required. Our study shows that scapular measurements based on 3D CT images in the modern Anatolian population show sexual dimorphism and may be useful for gender prediction in forensic anthropology. LL, TL and SSL measurements show statistically independent significance (Logistic Regression analysis) for gender determination. Even using the LL measurement of scapula alone is shown as a reliable and correct method since it provides over 90% accuracy in gender estimation. Forensic anthropologists may alternatively use the scapula bone if the skeletal parts which provide very high accuracy for gender determination, such as the pelvis and the skull, are damaged or not found.

Limitations

In our study, we think that up-to-date data on men and women belonging to a particular segment of modern Turkish society have been obtained. However, the data obtained were collected only from cases that applied to Muğla Sıtkı Koçman University Training and Research Hospital. We think that population-specific formulas can be developed for identification and this will contribute to forensic medicine and forensic anthropology with the data to be obtained by new studies with more cases in a wider area.

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