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# Sex Determination From Glenoid Cavity By Computed Tomography in Turkish Population

## Determinación del Sexo de la Cavidad Glenoidea Mediante Tomografía Computarizada en la Población Turca

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**SUMMARY:** The aim of this study is to contribute to sex determination studies from the scapula in the Turkish population and compare with previous studies. This study was performed with 200 scapulae (100 males and 100 females). The age range of the patients was between 18-93 years old. Computed tomography scans were used and length of glenoid cavity (LGC), breadth of glenoid cavity (BGC), depth of glenoid cavity (DGC), perimeter (PM) and volume (VL) were measured. Randomly selected 20 scapulae were measured three times for examine the intra-rater reliability from those measurements. Gender logistic regression analysis was conducted to find the significant variables at sex determination from the scapula. The most effective parameter in determining sex from scapula was found to be VL (88.5%). The effects of LGC, PM, BGC and DGC at sex determination from scapula were found to be 83%, 82.5%, 79.5%, 66%, respectively. The combination of VL and PM (89.5%) was found to be the most effective combination at sex determination from the scapula. The intraclass correlation values of all measurements were found to be at high reliability. According to the literature, PM and DGC along with the VL in Turkish population, were not used previously for sex determination from the scapula. A combination of the VL and PM was found to be the most effective parameters at sex determination from scapula in the Turkish population. There are few studies on the sex determination from scapula in the Turkish population. This study will guide anthropologists, forensic scientists and anatomists at sex determination studies from scapula and surgeons by morphometrically in clinical situations related to the scapula.

**KEY WORDS: Scapula; Glenoid cavity; Sex determination; Computed tomography.**

## INTRODUCTION

The scapula is a flat, triangular bone which is located on the posterior surface of the thorax. It has three borders: Superior, medial and lateral borders. The lateral border has a glenoid cavity which articulates with the head of the humerus (Drake *et al*., 2014). Skeletal remains are commonly found in crime scenes and mass graves and it is necessary to establish the individual's identity. While establishing the biological profile of human remains, sex, age at death and stature determination are commonly used. Sex determination is of primary importance because stature and age at death are sex-dependent characteristics (Özer *et al*., 2006). Fragmented or broken bones may be encountered due to post-mortem damage, environmental effects and taphonomic processes. Therefore, it is important to develop methods for determining sex from broken or fragmented bones (Prescher & Klümpen, 1995; St Hoyme & Iscan, 1989). The most effective method for sex determination is DNA analysis, but it is not possible to use it widely due to the cost-effectiveness and laboratory conditions (Varas & Leiva, 2012). Instead of DNA analysis, applications are made in forensic anthropology to determine sex, based on morphometric measurements and morphological features of bones (Krishan *et al*., 2016). For this purpose, morphometric measurements and morphological observations were made from the cranium and pelvis bones, and they appear as bones with high efficiency in sex determination (Steyn & Iscan, 2008; Williams & Rogers, 2006). In cases where the cranium and pelvis bones are fragmented or broken, sex determination

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studies must be carried out from other parts of the skeleton. Scapula is important bone at sex determination studies, which is a flat, short bone and was not given the same importance at sex determination as other long bones (Torimitsu *et al*., 2016). Morphometric changes are rare after the scapula when it completes development (Ross *et al*., 2011; Scholtz *et al*., 2010). Supraspinous and infraspinous fossa of the scapula is more commonly eroded by taphonomic processes, but the spine of the scapula and glenoid cavity is more resistant to such abrasions and can be used in forensic research (Prescher & Klümpen; St Hoyme & Iscan). Determination of sex studies from the scapula was made and for this purpose dry bone (Özer *et al*.), digital photography (Macaluso, 2011), computed tomography (Giurazza *et al*., 2013) and magnetic resonance imagination (Atamtürk *et al*., 2019) were used.

The aim of this study is to contribute to sex determination studies from scapula in the Turkish population and compare with previous studies.

## MATERIAL AND METHOD

**Data collecting:** This study was performed with 200 scapulae (100 males and 100 females). The patients who applied to Ankara City Hospital and had thorax computed tomography (CT) imagination were included in the study. Patients younger than 18 years old, with trauma, osteoporotic appearance and pathological condition of the scapula as seen in the thorax CT scans, were not included in the study. The age range of the patients was between 18-93 years old. Ethics committee approval was obtained from the ethics committee of Ankara City Hospital with the approval numbered E2-20-48.

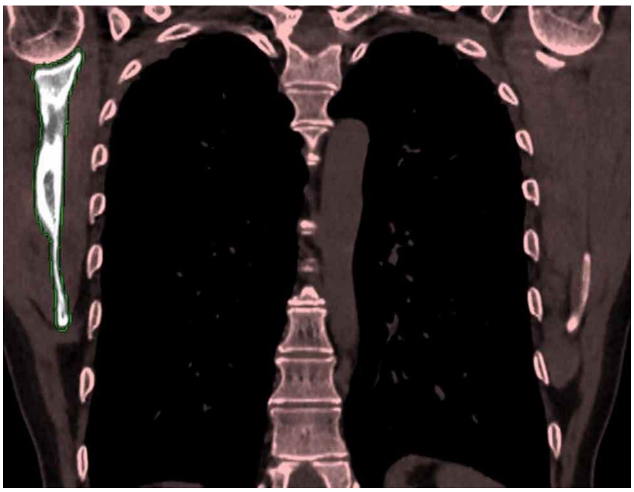

Fig. 1. Demonstration of segmentation of scapula.

**Scanning technique:** The scans were taken with GE Healthcare (USA) brand Revolution model two different CT devices (128 and 64 slices) in supine position and inspiration phase. Scanning technique parameters were; In the 128 and 64 section CT device, it had 100-120kV tube voltage, 130-200 mAs, 240 mA, 1.4 pitch with 1.3 mm collimation and 2.5 mm interval. The section thickness after the reformat was 2.5mm.

Non-contrast thorax CT scans of the patients were uploaded to the AW Volume Share 7 workstation with GE Healthcare brand Thoracic VCAR software for scapular measurements. Depth of the glenoid cavity (DGC) was measured at the coronal plane before the scapula were segmented. After that, the scapula was segmented all of the coronal, sagittal and transvers planes (Fig. 1.) and three-dimension scapula scan was obtained and breadth of the glenoid cavity (BGC), length of the glenoid cavity (LGC) and perimeter (PM) were measured, the volume (VL) of the segmented scapula was calculated with the volume measurement feature in the workstation (Fig. 2., Fig. 3., Fig. 4., Fig. 5.).

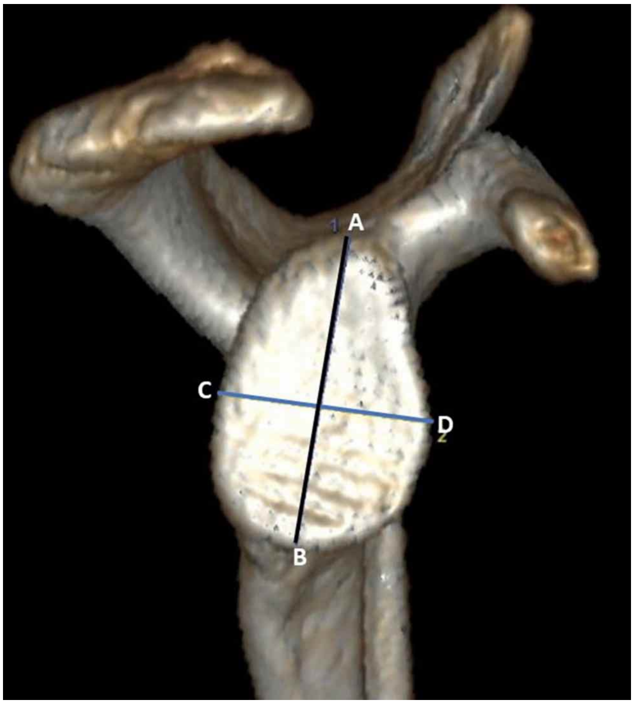


Fig. 2. Demonstration of measurement of length (between A and B) and breadth of glenoid cavity (between C and D).

**Statistical Analysis:** Descriptive statistics for continuous variables are given as mean (standard deviation), median (first and third quartile), and minimum-maximum values while. 20 randomly selected scapula were evaluated from a single rater three times. To examine the intra-rater reliability from those measurements, the intraclass correlation coefficient (ICC) was given. Besides, for comparing the measurements of males and


Fig. 3. Demonstration of measurement of the depth of glenoid cavity at the coronal plane (between E and F).

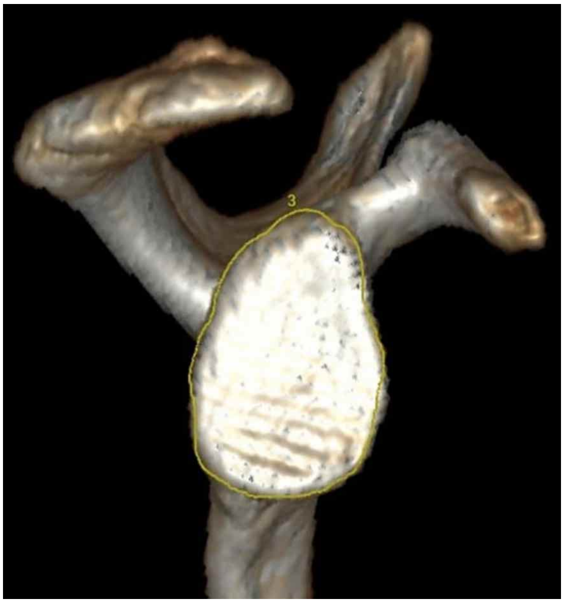


Fig. 5. Demonstration of measurement of the perimeter.


Fig. 4. Demonstration of measurement of volume.

females for 200 samples of scapula, the independent samples t-test or Mann-Whitney U test was conducted based on whether the normality assumption of the independent groups are satisfied or not. The Kolmogorov-Smirnov test is used for the normality test. To find the significant variables to model gender logistic regression analysis was conducted. Firstly, univariate logistic regression was applied and the variables with p-value<0.20 were chosen as candidate variables. With those candidate variables, multiple logistic regression analysis was run with backward elimination to find the final model. The correct classification rates are given for both univariate and the final models. The statistical significance was considered p-value<0.05. All analysis was performed by using IBM SPSS version 23.

**Parameters:** The parameters were measured in this study:

1) Length of glenoid cavity: Maximum distance across glenoid cavity perpendicular to anterior-posterior axis (Frutos, 2002) (LGC).

2) Breadth of glenoid cavity: Maximum distance across glenoid cavity measured at a right angle to the axis of length of glenoid cavity (Frutos) (BGC).

3) Depth of glenoid cavity: The superior and inferior poles of the glenoid cavity were positioned appropriately and the maximum depth of the glenoid cavity was determined and measured at the coronal plane (DGC).

4)Perimeter: Length of the enclosed profile of the glenoid cavity was drawn and measured (Macaluso) (PM).

5) Volume: The volume of the segmented scapula was calculated with the volume measurement feature in the workstation (VL)

The measurements of parameters were demonstrated in Fig. 2., Fig. 3., Fig. 4. and Fig. 5.

## RESULTS

The intraclass correlation values of all measurements were found to be at high reliability (Table I.). The descriptive statistical results of the measurements were summarized in Table II.

According to the results of univariate logistic regression analysis, the most effective parameter in determining sex from scapula was found to be VL (88.5%). The effects of LGC, PM, BGC and DGC at sex determination from scapula were found to be 83%, 82.5%, 79.5%, 66%, respectively (Table III.).

Multiple logistic regression analysis was performed and the combination of VL and PM (89.5%) was found to be the most effective combination at sex determination from the scapula (Table IV.).

Table I. Intraclass correlation and descriptive values of 20 randomly selected measurements.

| Variable (mm) | $\bar{X} \pm S$ | M (Q1-Q3) | Min-Max | ICC (95% CI) | p-value |
|---|---|---|---|---|---|
| BGC_1 | 26.79±3.66 | 27.15 (23.85-28.60) | 21.00-35.00 | | |
| BGC_2 | 26.92±3.76 | 27.45 (24.30-28.50) | 21.30-35.60 | | |
| BGC_3 | 26.94±3.70 | 27.35 (24.25-28.70) | 21.10-35.40 | 0.993 (0.985-0.997) | <0.001 |
| LGC_1 | 37.44±3.63 | 38.30 (34.40-40.15) | 29.50-42.60 | | |
| LGC_2 | 37.48±3.39 | 38.40 (34.65-40.00) | 30.40-42.10 | | |
| LGC_3 | 37.50±3.54 | 38.60 (34.45-39.95) | 30.00-43.00 | 0.990 (0.978-0.996) | <0.001 |
| DGC_1 | 4.93±1.56 | 4.45 (4.00-5.40) | 3.20-9.50 | | |
| DGC_2 | 4.94±1.68 | 4.45 (4.00-5.45) | 3.00-10.00 | | |
| DGC_3 | 5.02±1.55 | 4.55 (4.00-5.60) | 3.50-9.70 | 0.974 (0.946-0.986) | <0.001 |
| PM_1 | 109.32±11.03 | 111.85 (99.90-117.45) | 86.00-124.80 | | |
| PM_2 | 109.42±11.48 | 111.35 (99.60-117.80) | 86.30-125.10 | | |
| PM_3 | 109.42±11.34 | 110.85 (100.20-118.35) | 86.10-124.20 | 0.992 (0.984-0.997) | <0.001 |

BGC: breadth of glenoid cavity, LGC: length of glenoid cavity, DGC: depth of glenoid cavity, PM: perimeter.

Table II. Descriptive values of measurements.

| | Female | | | Male | | | |
|---|---|---|---|---|---|---|---|
| Variable | $\bar{X} \pm S$ | M (Q1-Q3) | Min-Max | $\bar{X} \pm S$ | M (Q1-Q3) | Min-Max | Test Statistic and p-value |
| VL ($cm^3$) | 88.47±12.25 | 88.06 (79.95-95.04) | 62.87-121.80 | 126.30±18.09 | 126.02 (111.34-139.63) | 92.63-167.64 | t=17.32, p<0.001 |
| BGC (mm) | 23.77±2.14 | 23.50 (22.20-24.90) | 19.40-33.80 | 27.83±2.69 | 27.70 (26.00-29.60) | 21.50-34.20 | U=-9.55, p<0.001 |
| LGC (mm) | 34.04±2.21 | 33.95 (32.53-35.70) | 29.20-39.20 | 38.54±2.61 | 38.50 (36.90-39.980) | 32.10-45.40 | t=13.18, p<0.001 |
| DGC (mm) | 4.17±1.35 | 4.00 (3.40-4.78) | 2.10-12.10 | 4.85±1.19 | 4.70 (4.20-5.50) | 2.00-9.70 | U=-4.665, p<0.001 |
| PM (mm) | 97.48±6.01 | 97.25 (92.95-101.53) | 83.80-117.50 | 111.26±8.47 | 110.95 (104.63-116.48) | 92.50-138.20 | t=12.83, p<0.001 |

VL: volume, BGC: breadth of glenoid cavity, LGC: length of glenoid cavity, DGC: depth of glenoid cavity, PM: perimeter..

Table III. Univariate logistic regression.

| | Univariate Logistic Regression Results | | Correct Classification Rate (%) | | |
|---|---|---|---|---|---|
| Variable | OR (95% CI) | p-value | Female | Male | Overall |
| VL | 0.842 (0.801-0.885) | <0.001 | 90 | 87 | 88.5 |
| BGC | 0.494 (0.409-0.597) | <0.001 | 79 | 80 | 79.5 |
| LGC | 0.452 (0.365-0.559) | <0.001 | 85 | 81 | 83 |
| DGC | 0.624 (0.478-0.814) | 0.001 | 68 | 64 | 66 |
| PM | 0.778 (0.727-0.833) | <0.001 | 86 | 79 | 82.5 |

VL: volume, BGC: breadth of glenoid cavity, LGC: length of glenoid cavity, DGC: depth of glenoid cavity, PM: perimeter, OR: odds ratio.

Table IV. Multiple logistic regression.

| | Multiple Logistic Regression Results | | Correct Classification Rate (%) | | |
|---|---|---|---|---|---|
| Variable | OR (95% CI) | p-value | Female | Male | Overall |
| VL | 0.866 (0.823-0.910) | <0.001 | 92 | 87 | 89.5 |
| PM | 0.881 (0.808-0.962) | 0.005 | | | |

VL: volume, PM: perimeter, OR: odds ratio.

## DISCUSSION

According to the literature, PM and DGC along with the VL in Turkish population, were not used previously for sex determination from the scapula. A combination of the VL and PM was found to be the most effective parameters at sex determination from scapula in the Turkish population.

The sex determination study from scapula was first performed by Dwight in 1894 and measured the length of the glenoid cavity and maximum scapular length. If the maximum scapular length was greater than 170 mm, the scapula was determined as male scapula and it was smaller than 140 mm, the scapula was determined as female scapula. He said that maximum scapular length is an effective parameter in sex determination from the scapula (Dwight, 1894).

The reliability and repeatability of the measurements are important. The parameter to be measured must be well defined and measured. For this, the measurements made within and between observers should not differ (Peckmann *et al*., 2016). In this study intraclass correlation values of all of the measurements were at high-reliability level and measurements of parameters were higher at male scapula than female scapula. The scapula is a dimorphic bone and the other studies also support this situation (El Morsi *et al*., 2017; Er *et al*., 2020; Hudson *et al*., 2016). Computed tomography is an effective imaging method for showing bone structures in skeletal measurements and scans can be stored in a small area and opened and worked on at any time (Giurazza *et al*.; Torimitsu *et al*.).

The fact that the scapula is a sexually dimorphic bone is the result of the complex relationship between genetic and environmental conditions. Gene interactions and hormonal activities play a role in sex differences (Anetzberger & Putz, 1996; Gajdos *et al*., 2009). The sex difference in the glenoid cavity begins at the pre-adolescence period and this is attributed to the different growth rates of males and females (Humphrey, 1998). The glenoid cavity of the scapula is more resistant to fragmentation than the supraspinous and infraspinous fossa of the scapula and is a better-protected area (Prescher & Klümpen; St Hoyme & Iscan, 1989).

Different results emerge when discriminant function analysis of a population is applied to another population. Therefore, sex determination studies specific to the population should be done (Peckmann *et al*.).

This study and the other studies have shown that a combination of variables instead of single variables gives higher values in sex determination (Atamtürk *et al*.; Di Vella *et al*., 1994; El Morsi *et al*.; Er *et al*., 2020; Özer *et al*.,

Table V. Studies on sex determination from scapula.

| Study | Sample size | Population | Parameters were used | The most effective parameter | Correct classification rate (%) | The most effective combination parameters | Correct classification rate (%) |
|---|---|---|---|---|---|---|---|
| Hudson *et al*. | 177 (101 males, | Mexican | LGC, BGC | BGC | 89.3 | BGC | 89.3 |
| Peckmann *et al*. | 114 (58 males, 56 | Chile | LGC, BGC | Left BGC | 85.1 | Left LGC, BGC | 86 |
| Özer *et al*. | 93 (47 males, 46 females) | East Anatolia (Medieval) | MSH, MSB, LGC, BGC | MSB | 94.8 | MSH, MSB, LGC, BGC | 95 |
| Di vella *et al*. | 80 (40 males, 40 females) | Apulian (Italy) | MSH, MSB, LGC, BGC, MDAC, MLA, MLC | MSB | 91.25 | MDAC, MLC, LGC | 95 |
| El Morsi *et al*. | 100 (50 males, 50 females) | Egypt | MSH, SB, MLS, LGC, BGC, MAH, LIL | Right MSH, SB | 82 | Right MSH ve sol MLS | 88 |
| Torimitsu *et al*. | 218 (109 males, 109 females) | Japan | MSH, MSB, LGC, BGC, MLS | Left MSH | 91.3 | Left MSH, MLS, BGC | 94.5 |
| Papaioannou *et al*. | 147 (81 males, 66 females) | Greece | MSH, SB, MLS, LGC, BGC, TLB, MAH, LIL | MSH | 91.2 | MLS, BGC | 95.9 |
| Atamtürk *et al*. | 204 (99 males, 105 females) | Turkey | LIL, MSB, MLS, LGC, LAB | MLS*LIL | 82.4 | MSB, LGC, LAB | 90.9 (at male) |
| Er *et al*. | 152 (71 males, 81 females) | Turkey | MSH, SB, MLS, LGC, BGC, TLB, MAH, LIL | BGC | 92.1 | MSH, SB, MLS, LGC, BGC, TLB, MAH, LIL | 96.7 |
| This study | 200 (100 males, 100 females) | Turkey | VL, LGC, BGC, DGC, PM | VL | 88.5 | VL, PM | 89.5 |

LGC: Length of glenoid cavity, BGC: breadth of glenoid cavity, DGC: depth of glenoid cavity, MSH: maximum scapular height, MSB: maximum scapular breadth, MDAC: maximum distance acromion-coracoid, MLC: maximum length of coracoid, SB: scapular breadth, MLS: maximum length of spine, MAH: maximum acromion height, LIL: length of infraspinous line, TLB: the thickness of the lateral border, LAB: length of the axial border, MDSSN: maximum depth of the suprascapular notch, VL: volume, PM: perimeter.

2006; Papaioannou *et al*., 2012; Peckmann *et al*.; Torimitsu *et al*.). The studies on the sex determination from the scapula and this study were summarized in Table V.

There are few studies on the sex determination from scapula in the Turkish population. This study will guide anthropologists, forensic scientists and anatomists at sex determination studies from scapula and may be surgeons by morphometrically in clinical situations related to the scapula.

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**ÜLKIR, M.; GÜNES¸, Y. C.; ÖZTÜRK, E.; KÖKSAL, M. & FARIMAZ, M.** Determinación del sexo de la cavidad glenoidea mediante tomografía computarizada en la población turca. *Int. J. Morphol. 40(3)*:774-780, 2022.

**RESUMEN:** El objetivo de este estudio fue contribuir a la determinación del sexo a partir de la escápula en la población turca y comparar con estudios previos. Esta investigación se realizó con 200 escápulas (100 hombres y 100 mujeres). El rango de edad de los pacientes estaba entre de 18 años y 93 años. Escaner de tomografía computada se usó para medir en la cavidad glenoidea los siguientes parámetros: longitud (LCG), ancho (ACG), profundidad (PCG), perímetro (PG) y volumen (VCG). Se midieron 20 escápulas seleccionadas tres veces al azar para examinar la confiabilidad intraevaluador de estas mediciones. Se realizó un análisis de regresión logística de género para encontrar las variables significativas en la determinación del sexo a partir de la escápula. El parámetro más eficaz para determinar el sexo a partir de la escápula resultó ser VCG (88,5%). Los efectos de LCG, PG, ACG y PCG en la determinación del sexo a partir de la escápula fueron del 83 %, 82,5 %, 79,5 % y 66 %, respectivamente. La combinación de VCG y PG (89,5%) resultó ser la combinación más efectiva en la determinación del sexo a partir de la escápula. Se encontró que los valores de correlación intraclase de todas las mediciones tenían una alta confiabilidad. De acuerdo con la literatura, PG y PCG junto con el VCG en la población turca, no se han utilizado previamente para la determinación del sexo a partir de la escápula. Se determinó que una combinación de VCG y PG son los parámetros más efectivos en la determinación del sexo a partir de la escápula. Existe escasa información sobre la determinación del sexo a partir de la escápula en la población turca. Este estudio guiará a los antropólogos, forenses y anatomistas en los estudios de determinación del sexo de la escápula y sera útil para los cirujanos en situaciones clínicas relacionadas con la escápula.

**PALABRAS CLAVE: Escápula; Cavidad glenoidea; Determinación del sexo; Tomografía computarizada.**

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