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Morphometric Measurements of the Hip Bone in Turkish Adult Population

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Objectives: Coxal bone paticipates in the formation of the pelvic skeleton. Anatomy knowledge on coxafemoral joint as well as careful history taking and physical examination are crucial in evaluation and management of disorders involving hip joint. The aims of the present study were to perform morphometric measurements of the human coxal bones, calculation of their articular surface areas and report the range of these parameters regarding Turkish adult population. Methods: Seventy-two dry human adult coxal bones (39 left and 33 right) from the Anatomy Departments of Erciyes University, Inonu University and Kahramanmaras Sutcu Imam University were measured using a caliper sensitive to 0.1 mm. Morphometric measurements were performed through 22 parameters determined. While 19 of these parameters were related to the distance between two points and thicknesses in various parts of the bone, the remaining three were related to the determination of articular surface areas. The articular surface areas of hip bone (facies auricularis (FA), facies lunata (FL) and facies symphsialis (FS)) were calculated with ImageJ software program. Results: The average values of facies auricularis area were 1659.04 ± 470.92 mm^2 and 1637.32 ± 460.15 mm^2 on the left and right coxal bones, respectively. No statistically significant difference was determined between the left and right coxal bone measurements ($p > 0.05$). We found a positive and significant correlation between articular surface areas of facies auricularis (FA), facies lunata (FL) and facies symphysialis (FS) and maximum width of ilium ($r_{FA} = 0.299$, $r_{FL} = 0.276$, $r_{FS} = 0.375$, respectively and $p < 0.05$), and distance between spina ilica anterior superior and the upper edge of facies symphysialis ($r_{FA} = 0.268$, $r_{FL} = 0.511$, $r_{FS} = 0.482$, respectively and $p < 0.05$). Conclusion: The distribution and mean values of coxal bone morphometric measurements usually differ between individuals and human populations. With this regard, orthopedic surgeons should be aware of the diversity in components of coxal bone dimensions although implants and hip prosthesis components of different sizes are manufactured. Safe routes and estimated distances should be considered during surgical procedures to avoid complications.

INTRODUCTION

Hip bone is one of the major bones in the human skeleton. It is formed by three separate bones called ilii, ischii and pubis during the preadult period and is directly involved in childbirth (1). Besides, it contains acetabular cavity which forms the most stable ball-and-socket joint in the body, articulatio coxae, with head of the femur (2,3). Acetabulum is formed by os ilii (40%), os ischii (40%) and os pubis (20%) at certain ratios (4). When we look into the acetabulum, there is fossa acetabuli (cotyloid cavity) containing fibroadipose tissue covered with synovial tissue and facies lunata in the shape of a horse shoe (5). The shape and dimensions of acetabulum are variable between individuals. Minor anatomical abnormalities in the acetabular shape, joint

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congruences are frequent (6). These differences can be age, gender or race related (7-9). Some authors reported the specific features for coxal bones in adult Turkish population. The shape of acetabuli and anterior acetabular ridges were mentioned to be curved and straight type, respectively (6,10). Hip joint, which connects lower extremities and axial skeleton, plays an important role in the static and dynamic physiology of the locomotor system (11). Acting as a lever between body weight and hip abductor muscle force, it maintains the equilibrium between these forces. Thus, pelvis is stabilized through the gait cycle. The pelvic skeleton and hip joint contain important vascular, neural, genitourinary structures and part of the gastrointestinal tract. Unstable pelvic ring injuries usually occur in patients suffering high energy trauma and are associated with high mortality and morbidity rates (12-14). The anthropometric study of the acetabulum can be helpful to the orthopedic surgeons in presurgical planning of interventions for hip fractures, disorders and arthroplasty (15). The goal of surgical fixation is the reconstruction of the spine-pelvic-junction to allow early weight-bearing and to facilitate nursing care, particularly for multiple injured patients (16). On the other hand, chronic degeneration or surgical intervention related changes of hip structure produce altered loading and mechanical stress in coxafemoral joint (17). The unusual loading resulting from these changes causes hip pain which is secondary to incongruent hip joint and pathologic wear of acetabular and femoral head cartilage (18-20). Compared to other joints, hip joint disorders are more challenging to diagnose (21). Therefore, anatomy knowledge on coxafemoral joint as well as careful history taking and physical examination are crucial in evaluation and management of disorders involving hip joint (17).

The aims of the present study were to perform morphometric measurements of the adult human coxal bones, calculation of their articular surface areas and report the range of these parameters regarding Turkish adult population.

MATERIALS AND METHODS

The study was conducted on 72 dry adult hip bones (39 left and 33 right hip bone) of unknown gender and age, collected from the osteological collections from the Anatomy Departments of Erciyes University, Inonu University and Kahramanmaras Sutcu Imam University. Morphometric measurements were performed through 22 parameters as determined in Table I. Nine-teen of these parameters were related to distances between two points and thickness in various parts of the bone, the remaining three were related to the determination of articular surface areas. A digital caliper sensitive to 0.1 mm was used for the measurements performed on the bone. Each bone was photographed anteriorly with a distance of 1 m to determine the articular surface areas digitally. The articular surface areas of hip bone (FA, FL and FS) were calculated with ImageJ software program (https://imagej.nih.gov/ij/download.html), (Fig 1). The calibration setting was made between the original and the photography to get correct results from the measurement (Fig 2).

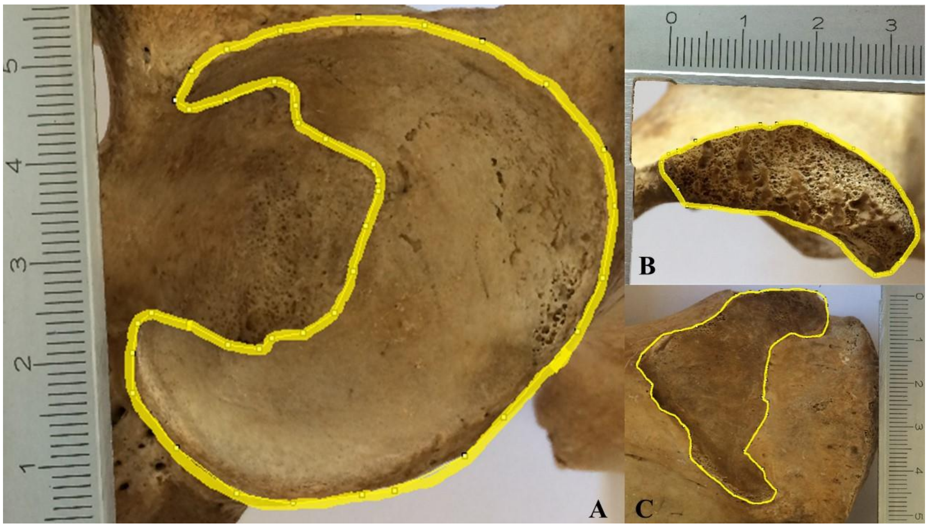

Figure 1. Calculation of articular surface areas with Image J program (A: FL, B: FS, C: FA)

Statistical Analysis

IBM SPSS Statistics for Windows (Version 22.0, Armonk, NY, USA) was used for statistical analyses. The Shapiro-Wilk test was preferred to determine the normal distribution of the data. After determining the normal distribution, difference between the right and left bones was analyzed by the Independent Samples t-test. The correlations of measurement-based parameters were determined by the Pearson’s correlation test. Values of $p < 0.05$ were considered statistically significant.

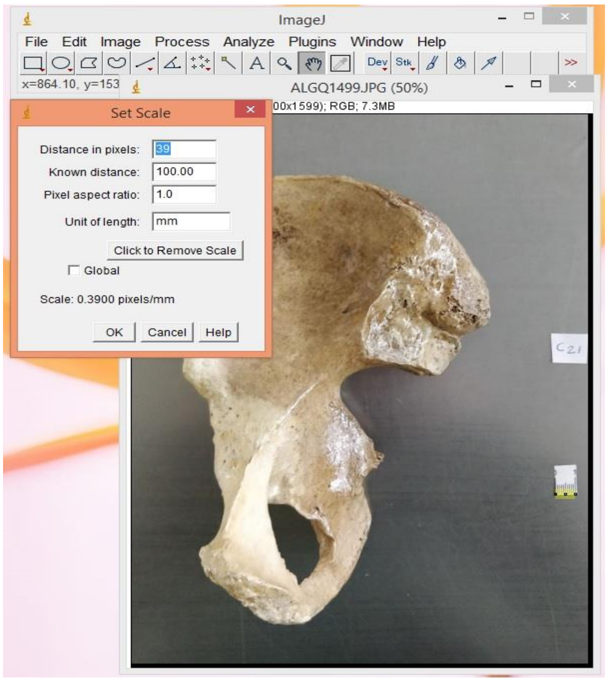

Figure 2. Calibration setting in ImageJ program

RESULTS

A total of 72 dry hip bones, 39 from the left side and 33 form the right side, were used within the scope of the study. The details of the abbreviations of the measurement parameters are presented in Table I.

Table I. Definition of measurement parameters.

Array	Measurement Points
1	Maximum width of ilium or width of hip bone (MAWI)
2	Minimum width of ilium (MIWI)
3	Distance between spina iliaca anterior inferior (SIAI) and spina iliaca posterior inferior (SIPI)
4	Distance between the most protruding point of tuber iliacum (TI) and spina iliaca anterior superior (SIAS)
5	Distance between spina iliaca anterior inferior (SIAI) and spina iliaca anterior superior (SIAS)
6	Distance between spina iliaca posterior superior (SIPS) and spina iliaca posterior inferior (SIPI)
7	Distance between spina iliaca posterior superior (SIPS) and the upper edge of the acetabulum (AC)
8	Distance between spina iliaca anterior superior (SIAS) and the nearest edge of the acetabulum (AC)
9	Shortest distance between spina iliaca anterior superior (SIAS) and the anterior edge of facies auricularis (FA)
10	Shortest distance between lower edge of spina iliaca anterior inferior (SIAI) which fused with acetabular edge and anterior edge of facies auricularis (FA)
11	Thickness of os ilium at tuberculum iliacum (TI)
12	Width of tuber ischiadicum
13	Distance between the most protruding point of tuberculum pubicum (TP) and the nearest edge of acetabulum (AC)
14	Height of facies symphysialis (FS)
15	Width of facies symphysialis (FS)
16	Medio-inferior wall thickness of acetabulum (AC)
17	Width of incisura acetabuli (IA)
18	Distance between spina iliaca anterior superior (SIAS) and the upper edge of facies symphysialis (FS)
19	Distance between spina iliaca anterior inferior (SIAI) and the upper edge of facies symphysialis (FS)
20	Articular surface area of facies auricularis (FA)
21	Articular surface area of facies symphysialis (FS)
22	Articular surface area of facies lunata (FL)

The descriptive analyses of the morphometric parameters of the hip bone were performed, and the mean and standard deviation values were presented in Table II. When the average values of the articular surface areas were examined, it was determined that the articular surface areas of the FA, FL and FS were 1648.18 ± 461.73 mm^2, 2990.79 ± 766.93 mm^2 and 1727.98 ± 479.96 mm^2, respectively. No statistically significant difference was found between parameters of the right and left hip bone ($p > 0.05$).

Table II. Mean values of the measured parameters.

Parameters	n	Mean ± SD	Minimum	Maximum
MAWI	72	153.22 ± 9.96	128.52	182.49
MIWI	72	62.12 ± 5.65	51.86	78.54
Distance between SIAI and SIPI	72	117.51 ± 7.70	99.68	139.83
Distance between the most protruding point TI and SIAS	72	60.33 ± 10.15	39.16	95.46
Distance between SIAI and SIAS	72	41.46 ± 5.02	28.10	52.95
Distance between SIPS and SIPI	72	29.10 ± 5.25	18.92	39.46
Distance between SIPS and the upper edge of AC	72	106.24 ± 12.63	61.96	124.91
Distance between SIAS and the nearest edge of AC	72	60.30 ± 5.46	46.14	75.78
Shortest distance between SIAS and the anterior edge of FA	72	93.40 ± 6.25	78.50	111.21
Shortest distance between lower edge of SIAI which fused with AC edge and anterior edge of FA	72	71.67 ± 4.52	58.18	82.20
Thickness of os ilium at TI	72	17.50 ± 2.64	12.05	25.26
Width of tuber ischiadicum	72	25.46 ± 3.29	17.55	32.94
Distance between the most protruding point of TP and the nearest edge of AC	72	61.75 ± 9.20	43.08	78.86
Height of FS	72	37.70 ± 4.14	28.74	47.62
Width of FS	72	16.28 ± 2.08	10.16	19.91
Medio-inferior wall thickness AC	72	5.74 ± 1.45	2.31	8.87
Width of IA	72	22.50 ± 3.50	15.27	30.61
Distance between SIAS and the upper edge of FS	72	132.79 ± 10.43	102.40	152.49
Distance between SIAI and the upper edge of FS	72	102.69 ± 8.18	75.13	120.11
Articular surface area of FA	72	1648.18 ± 461.73	820.59	2963.34
Articular surface area of FS	72	1727.98 ± 479.96	722.566	3406.21
Articular surface area of FL	72	2990.79 ± 766.93	1684.33	5391.32

We found positive and significant correlations between FA and MAWI (r = 0.299, p = 0.020), distance between SIAI and SIPI (r = 0.363, p = 0.004), distance between SIAI and SIAS (r = 0.259, p = 0.046), distance between SIPS and the upper edge of AC (r = 0.426, p = 0.001), thickness of os ilium at TI (r = 0.304, p = 0.018), height of FS (r = 0.348, p = 0.006) and distance between SIAS and the upper edge of FS (r = 0.268, p = 0.038), (Table III, IV and V).

Table III. Correlation between articular surface area of facies auricularis and other parameters.

		FA Joint Surface Area	
Parameters	**n**	**r**	**p**
MAWI	72	0.299	**0.020***
MIWI	72	0.248	0.056
Distance between SIAI and SIPI	72	0.363	**0.004***
Distance between the most protruding point TI and SIAS	72	0.186	0.154
Distance between SIAI and SIAS	72	0.259	**0.046***
Distance between SIPS and SIPI	72	0.208	0.111
Distance between SIPS and the upper edge of AC	72	0.426	**0.001***
Distance between SIAS and the nearest edge of AC	72	-0.001	0.993
Shortest distance between SIAS and the anterior edge of FA	72	0.167	0.201
Shortest distance between lower edge of SIAI which fused with AC edge and anterior edge of FA	72	0.073	0.577
Thickness of os ilium at TI	72	0.304	**0.018***
Width of tuber ischiadicum	72	0.129	0.326
Distance between the most protruding point of TP and the nearest edge of AC	72	0.017	0.898
Height of FS	72	0.348	**0.006***
Width of FS	72	0.147	0.264
Medio-inferior wall thickness AC	72	-0.008	0.950
Width of IA	72	0.092	0.486
Distance between SIAS and the upper edge of FS	72	0.268	**0.038***
Distance between SIAI and the upper edge of FS	72	0.247	0.058
Articular surface area of FA	72	0.081	0.540
Articular surface area of FS	72	0.246	0.058

*Difference is statistically significant; Pearson's correlation test, $p < 0.05$

We also found positive and significant correlations between FL and MAWI (r = 0.259, p = 0.046), distance between the most protruding point of TI and SIAS (r = 0.296, p = 0.022), width of tuber ischiadicum (r = 0.488, p = 0.000), height of FS (r = 0.257, p = 0.048), width of FS (r = 0.317, p = 0.014), width of IA (r = 0.443, p = 0.046), distance between SIAS and the upper point of FS (r = 0.511, p = 0.000), distance between SIAI and the upper edge of FS (r = 0.363, p = 0.000) and articular surface area of FS (r = 0.406, p = 0.000) (Table III, IV and V). A positive and significant correlations was noted between FS and MAWI (r = 0.375, p = 0.003), MIWI (r = 0.306, p = 0.017), thickness of os ilium at TI (r = 0.348, p = 0.006), width of tuber ischiadicum (r = 0.325, p = 0.011), width of FS (r = 0.617, p = 0.000), distance between SIAS and the upper point of FS (r = 0.482, p = 0.000), distance between SIAI and the upper edge of FS (r = 0.374, p = 0.003), articular surface area of FL (r = 0.406, p = 0.001), (Table III, IV and V).

Table IV. Correlation between articular surface area of facies lunata and other parameters.

	FL Joint Surface Area		
Parameters	**n**	**r**	**p**
MAWI	72	0.276	**0.033***
MIWI	72	0.071	0.587
Distance between SIAI and SIPI	72	0.104	0.431
Distance between the most protruding point TI and SIAS	72	0.296	**0.022***
Distance between SIAI and SIAS	72	0.234	0.072
Distance between SIPS and SIPI	72	0.091	0.487
Distance between SIPS and the upper edge of AC	72	0.012	0.930
Distance between SIAS and the nearest edge of AC	72	0.183	0.161
Shortest distance between SIAS and the anterior edge of FA	72	0.245	0.059
Shortest distance between lower edge of SIAI which fused with AC edge and anterior edge of FA	72	-0.158	0.229
Thickness of os ilium at TI	72	0.133	0.311
Width of tuber ischiadicum	72	0.488	**0.000***
Distance between the most protruding point of TP and the nearest edge of AC	72	0.076	0.566
Height of FS	72	0.257	**0.048***
Width of FS	72	0.317	**0.014***
Medio-inferior wall thickness AC	72	0.125	0.340
Width of IA	72	0.443	**0.000***
Distance between SIAS and the upper edge of FS	72	0.511	**0.000***
Distance between SIAI and the upper edge of FS	72	0.363	**0.004***
Articular surface area of FA	72	0.081	0.540
Articular surface area of FS	72	0.406	**0.001***

*Difference is statistically significant; Pearson's correlation test, $p < 0.05$

Table V. Correlation between articular surface area of facies symphysialis and other parameters

	FS Joint Surface Area		
Parameters	**n**	**r**	**p**
MAWI	72	0.375	**0.003***
MIWI	72	0.306	**0.017***
Distance between SIAI and SIPI	72	0.226	0.082
Distance between the most protruding point TI and SIAS	72	0.251	0.053
Distance between SIAI and SIAS	72	0.162	0.215
Distance between SIPS and SIPI	72	-0.030	0.822
Distance between SIPS and the upper edge of AC	72	-0.017	0.899
Distance between SIAS and the nearest edge of AC	72	0.246	0.058
Shortest distance between SIAS and the anterior edge of FA	72	0.154	0.241
Shortest distance between lower edge of SIAI which fused with AC edge and anterior edge of FA	72	-0.027	0.840
Thickness of os ilium at TI	72	0.348	**0.006***
Width of tuber ischiadicum	72	0.325	**0.011***
Distance between the most protruding point of TP and the nearest edge of AC	72	0.250	0.054
Height of FS	72	0.247	0.057
Width of FS	72	0.617	**0.000***
Medio-inferior wall thickness AC	72	0.235	0.071
Width of IA	72	0.118	0.368
Distance between SIAS and the upper edge of FS	72	0.482	**0.000***
Distance between SIAI and the upper edge of FS	72	0.374	**0.003***
Articular surface area of FA	72	0.246	0.058
Articular surface area of FL	72	0.406	**0.001***

*Difference is statistically significant; Pearson’s correlation test, $p < 0.05$

DISCUSSION

Pelvic injuries and fractures occur as a result of high-energy traumas such traffic accidents, falling down from height, and crushing in adolescents and adults (22). Knowledge on the morphometric features of hip are of great importance in the treatment of these pelvic injuries since it is beneficial in the determination of surgical technique and sizes of materials to be used as in the hip replacement surgery or plate-screw fixation (23).

In the literature, there are studies reporting the secure distance and ways for screw placement to the hip bone (24-26). Berry et al. measured the distance between SIPS and the top edge of AC. The distances between SIPS-AC were calculated to be 128.2 ± 6.8 mm and 124.9 ± 7.1 mm in males and females, respectively (26). In our study, the SIPS-AC distance was calculated to be 106.24±12.63 mm on average. The SIPS-AC distance in the present study was found to be lower than the values of Berry et al. (26). The difference is can be attributed to racial differences.

It is assumed that greater articular surface of acetabulum provided better grip of the femoral head inside the acetabulum and ensured better results for arthroplasty (31). Additionally, Esenkaya pointed out that knowing of the FA articular surfaces area is important for screw-plate fixation and is helpful for selecting the appropriate screw-plate fixation in sacroiliac fracture surgery (28). Esenkaya measured the FA articular surface area as 18.6 mm^2 (28). Krmek et al. presented average facies auricularis surface area as 13.46 ± 2.32 cm^2 on dry os coxal bones (29). Fien et al. reported facies auricularis surface area as 1364.32 ± 207.508 mm² (30). Facies lunata surface areas measurements were found to be 21.70 ± 3.62 (16–33) cm^2 (6) and 2294 ± 329 mm^2 (31) on dry coxal bones. In our study, we found facies auricularis surface areas as 1648.18 ± 461.73 mm^2, facies lunata surface areas as 2990.79 ± 766.93 mm^2 and facies smphysialis surface areas as 1727.98 ± 479.96 mm^2. Our results were in line with aforementioned studies. We suggest the use of different measurement techniques being responsible for minor differences in studies.

The size of iliac bone thickness, reported by various studies, generally provides useful information for screw placement through the bone. In Esenkaya's study investigating the technique of sacroiliac screw and plate placement, morphometric measurements were performed on 20 hip bones. The ilium thickness was measured from four different regions (FA front section, 2 cm ahead of FA and SIPI, FA adjacent section and the general average of all regions) according to FA, and it was determined that the ilium thickness varied between 14 and 28 mm (mean 19.2 mm) (28). Berry et al (26) measured the ilium thickness for safe intra-iliac screw placement, and the mean thickness value was reported to vary between 14-30 mm. Miller et al. reported the mean thickness of the ilium as 14-30 mm (25). In our study, the thickness of the ilium varied between 12.05 and 25.26 mm (mean 17.50 ± 2.64 mm). It was also significantly associated with FS and FA articular surface areas.

Dhindsa et al. (32) found that mean width of hip bone was 14.0 ± 0.78 cm. Singh and Raju reported that the width of hip bone was 14.32 cm on the right side and 14.35 cm on the left side in males, whereas in females the values were 13.78 cm on both right and left sides (7). Maruyama et al. reported that in males, the width of the hip bone was 13.6 cm and in females it was 13.1 cm (33). In the present study, mean width of hip bone was 153.22 ± 9.96 and was significantly associated with all three articular surface areas. The difference of the measured areas between two compared studies can be explained by difference in gender distribution of the study groups. Lack of information on age, gender and medical history of cadavers from which coxal bones were obtained was the the limitation of the present study. Another limitation was the calculation of articular surface on bone photograph because it is curved in shape and have irregular surface in all three dimensions. The distance between SIAS and the upper edge of FS were associated with dimensions of all three articular surface areas. The association between the aforementioned measurements can be attributed to proportional growth of coxal bone components.]

The distribution and mean values of coxal bone morphometric measurements usually differ between individuals and human populations. With this regard, orthopedic surgeons should be aware of the diversity in components of coxal bone dimensions although implants and hip prosthesis components of different sizes are manufactured. Safe routes and estimated distances should be considered during surgical procedures to avoid complications. In addition, these results can serve as guideline for further studies.

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