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Evaluation of coccyx morphometry through computed tomography images in terms of age and sex in anatolian population

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Abstract

The aim of this study is the evaluation of coccyx morphology and morphometry with parameters obtained through multi-detector computed tomography (MDCT) images of Turkish population in terms of sex and age groups. This retrospective study was conducted on the MDCT pelvic images of 640 (320 female-320 male) individuals between the ages of 20 and 99. The parameters of number of coccyx, the number of coccyx segment, coccyx straight length, coccyx curvature length, coccyx thickness, coccyx area, sacrococcygeal joint angle, intercoccygeal joint angle, coccyx curvature index, coccyx width, coccyx deviation angle, coccyx deviation, sacrococcygeal-horn fusion and sacrococcygeal-lateral process fusion were measured. All morphometric parameters measured on coccyx except for sacrococcygeal joint angle were found to be statistically significantly higher in males when compared with females. Sacrococcygeal joint angle parameter was found to be statistically significantly higher in females ($p<0.05$). In terms of decades, significant results were found between sexes as age increased. In the Logistic Regression (LR) conducted to evaluate the effect of measured parameters on sex, accuracy rate was found as 96.4%. According to the age prediction LR analysis, accuracy rate was found as 76.4% in females and as 70.3% in males. As a result of our study, we believe that coccyx shows significant difference between sexes and during old age, and coccyx changes significantly when compared with the young. We believe that our study will make important contributions to literature and future studies.

Keywords: Coccyx morphometry, sex estimation, age estimation, computed tomography, logistic Regression

Introduction

One of the most important challenges in forensic studies is the determination of biological identity from unidentified remains. In such cases, age and sex estimation from skeletal remains facilitates and accelerates the identification of individuals [1]. Although genetic, biochemical, histological and similar methods are used to make these determinations in forensic analyses, most of these methods are performed in long periods of time and with high costs [2]. Osteometry is a method that enables high-accuracy, effective, cost-effective and quick decisions to be made. [3,4].

Osteometry studies performed with computed tomography (CT) are the most reliable radiographic technique [3]. Identification studies based on CT images are frequently preferred by forensic anthropologists since they provide more accurate results than traditional methods, they are reproducible and they allow for visualization of each part of the bone [2,5,6].

The structure which consists of the last 3-5 rudimentary vertebrae of the vertebral column that is sometimes directly fused, and which articulates with the final segment of the sacrum is called coccyx [7]. Coccyx supports the pelvic floor by connecting with many ligaments and muscles, carries weight in the sitting position and provides positional support to the anus [8,9]. It is considered to be a very small part of the vertebral column with relatively little function [8]. However, according to Muslim and Jewish beliefs, it is believed that its

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structure is preserved after death and that the body will be built on this bone during resurrection. In Muslim books, the importance of this bone is emphasised by giving it the special name 'Ajbu'z-zeneb' [10].

In a large number of studies conducted so far, a large number of bones have been used for age and sex determination including the sternum [11], phalanx [12], tooth [13] and cranium [14]. There are few studies on the morphometry and morphology of coccyx [8]. The aim of this study is sex and age estimation by evaluating coccyx morphology and other parameters. Another aim is the examination of lateral deviation of coccyx, morphological and morphometrical characteristics of coccyx according to decades.

Material and Methods

CT images of 320 women and 320 men aged 20–99 who were admitted to İzmir Bakırçay University Education and Research Hospital between 1 January 2018 and 1 October 2023 were randomly included in this retrospective study. Individuals without fractures or masses detected on CT scans were included in the study. Personal data such as weight, height, obesity status, environmental and genetic factors are unknown. Permission was obtained from the Non-interventional Local Ethics Committee for the study (Reference Number: 1085/2023).

Image Analysis

The images were obtained from CTs taken using a 16-row multi-detector computed tomography (MDCT) scanner located at Çiğli Training and Research Hospital, İzmir Bakırçay University, with a slice thickness of 5 mm. (Tube voltage: 120 kV, gantry rotation: 0.75 s, and pitch: 1.0 mm.) All measurements were performed on a Horos (v3.3.06) workstation. The images were analysed using two- and three-dimensional reconstructions (Multi Planar Reconstruction-MPR, Maximum Intensity Projection-MIP) with a standard bone window. Sagittal, coronal, and transverse images focused on the coccyx were brought into the orthogonal plane with standard magnification. In the study, the orthogonal plane was set to pass through the promontory in the sagittal plane, the vertebral bodies in the coronal plane, and both the spinous process and the pubic symphysis in the transverse plane [15]. The three-dimensional image was superimposed to obtain a single image. Number of coccyx (CS) and number of coccyx segment (CSS) were evaluated. Coccyx was classified in six types as type I (mildly curved coccyx), type II (more markedly curved coccyx), type III (coccyx pointing anteriorly), type IV (anterior subluxation coccyx), type V (coccyx with retroversion), type VI (scoliotic coccyx) according to coccygeal typing determined by Nathan et al. [16].

Measured Parameters

Coccyx Straight Length (CSL): The length between the superior anterior ends of the first coccygeal vertebra and the last coccygeal vertebra.

Coccyx Curvature Length (CCL): The length of the anterior curvature from the first coccygeal vertebra to the last coccygeal vertebra.

Coccyx Thickness (CT): The shortest length passing through the anteroposterior line of the first coccygeal vertebra.

Coccyx Area (CA): The area of the coccyx from the origin of the first coccygeal vertebra to the end of the last coccygeal vertebra.

Sacrococcygeal Joint Angle (SJA): The acute angle between the line passing through the superior-inferior midline of the fifth sacral vertebra to the superior and interior midline of the first coccygeal vertebra.

Intercoccygeal Joint Angle (IJA): The acute angle between the line passing through the superior-inferior midline of the first coccygeal vertebra and the line passing through the superior-inferior midline of the last coccygeal vertebra.

Coccyx Curvature Index (CCI): Straight length / curved length × 100.

Coccyx Width (CW): The widest length on the right-left line of the first coccygeal vertebra.

Coccyx Deviation Angle (CDA): The angle between the lowest point of the coccyx and the line passing through the centre of the sacrum (Fig 1).

Coccyx Deviation (CD): Direction of deviation of the coccyx.

Sacrococcygeal-Horn Fusion (SHF): Fusion between the sacral horn of the sacrum and the horns of the first coccygeal vertebra.

Sacrococcygeal-Lateral Process Fusion (SLPF): Fusion between the transverse process of the sacrum and the transverse process of the first coccygeal vertebra.

Thirty individuals were measured again by the radiologist three weeks later.

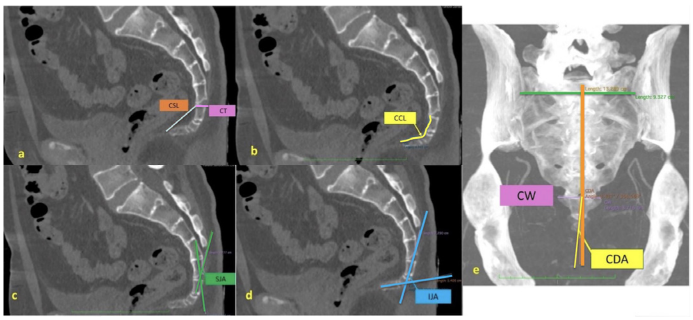

Figure 1. On Sagittal plane a) CSL: coccyx straight length, CT: coccyx thickness; b) CCL: coccyx curvature length; c) SJA: sacrococcygeal joint angle; d) IJA: intercoccygeal joint angle; On Coronal plane e) CW: coccyx width, CDA: coccyx deviation angle

Statistical Analysis

All data were analysed by using SPSS 22, Minitab 17. Reliability analysis was conducted. Descriptive statistics (mean and standard deviation) were calculated for the parameters and presented. The conformity of data set of measurements to normal distribution was evaluated with Anderson Darling test. Chi-Square Test was used to evaluate the categorical data. Mann Whitney U test was conducted since evaluation according to sex did not conform to normal distribution. While evaluating the distribution of age in terms of decades, Kruskal Wallis H test was used in parameters which were not normally distributed. Logistic Regression (LR) analysis was used to evaluate sex. Intra-observer reliability Intra-class Correlation Coefficient (ICC) was calculated since two observations were made. $p<0.05$ was considered significant.

Results

A total of 640 individuals, 320 females and 320 males, were included in the study. Age was analysed by decades. 40 women and 40 men were included in each decade. While the mean age of men was 59.10±1.25, the mean age of women 59.35±1.26. No significant difference was found in age in terms of sex ($p>0.05$). CSL, CCL, CT, CA, IJA, CW and CDA parameters were higher in males, while SJA parameter was higher in females, which was statistically significant ($p<0.05$). Although CCI was high in females, it was not found to be statistically significant ($p>0.05$) (Table 1).

Table 1. Evaluation of coccyx measurements in terms of sex

Parameters	Female (n=320)	Male (n=320)	p
CSL	2.80 (1.37-4.45)	3.50 (0.97-6.08)	**0.000**
CCL	3.01 (1.51-5.39)	4.03 (0.77-7.29)	**0.000**
CT	0.82 (0.57-1.28)	1.04 (0.49-1.52)	**0.000**
CA	2.30 (1.05-4.66)	3.36 (0.96-7.35)	**0.000**
SJA	19.12 (5.23-76.79)	13.66 (1.93-72.67)	**0.000**
IJA	36.42 (8.33-92.63)	39.59 (0-131.89)	**0.000**
CCI	95.40 (38.99-202.86)	88.24 (63.15-125.97)	0.141
CW	2.93 (1.44-4.26)	3.58 (1.77-7.06)	**0.000**
CDA	5.58 (0-38.50)	13.30 (1.50-61.60)	**0.000**

$p<0.001$; CSL: coccyx straight length; CCL: coccyx curvature length; CT: coccyx thickness; CA: coccyx area; SJA: sacrococcygeal joint angle; IJA: intercoccygeal joint angle; CCI: coccyx curvature index; CW: coccyx width; CDA: coccyx deviation angle

It was found that CS did not differ in terms of sex ($p=0.277$). CSS was found as two segments in females and one, three and four segments in males, which was significant ($p<0.000$). It was found that CD was not significant in females. While it was higher on the right side in males, it was found to be significant in left deviation ($p<0.000$). SHF did not differ by sex ($p=0.162$). Absence of fusion in females and bilateral fusion in males were found to be significant ($p<0.000$) (Table 2). When the distribution of coccyx types was examined in terms of sex, the presence of type I and type III in females and the presence of type V in males was found to be significant (X2=59.879; (5), $p<0.001$) (Figure 2).

Figure 2. Classification diagram

Table 2. Distribution of categorical variables by sex (n=640)

Parameters		Total	Female	Male	X^2	p
CS	3	229	120	109	2.569	0.277
	4	347	164	183		
	5	64	36	28		
CSS	1	31	8	23	44.986	**0.000**
	2	289	185	104		
	3	281	115	166		
	4	39	12	27		
CD	Straight	112	112	0	140.631	**0.000**
	Left deviated	280	122	158		
	Right deviated	247	85	162		
SHF	No	371	182	189	5.137	0.162
	Left	38	15	23		
	Right	44	28	16		
	Bilateral	187	95	92		
SLPF	No	550	288	262	26.389	**0.000**
	Left	27	17	10		
	Right	26	11	15		
	Bilateral	37	4	33		

$p<0.001$, CS: number of coccyx, CSS: number of coccyx segment, CD: coccyx deviation, SHF: sacrococcygeal-horn fusion, SLPF: sacrococcygeal-lateral process fusion

When coccyx was analysed in terms of decades in females, it was found to be smaller in individuals in their 2nd and 4th decades than individuals in their 6th decade only in IJA parameter, which was significant ($p=0.02$). No significant difference was found in other morphometric parameters in terms of age ($p>0.05$) (Table 3). In females, CS parameter was found to be 3 in the 7th and 9th decades and 4 in the 2nd decade and this result was found

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to be significant (X^2=39.492; (14), p<0.001). The result that there were two segments in the 8th decade of CSS parameter was found to be significant (X^2=5.921; (21), p<0.05). Absence of fusion or bilateral fusion in the third decade in SHF parameter and the presence of left fusion in the 4th decade was found to be significant (X^2=5.921; (21), p<0.05). When CD, SLPF parameter and coccyx types were examined in terms of decades, no significant difference was found between groups (p>0.05).

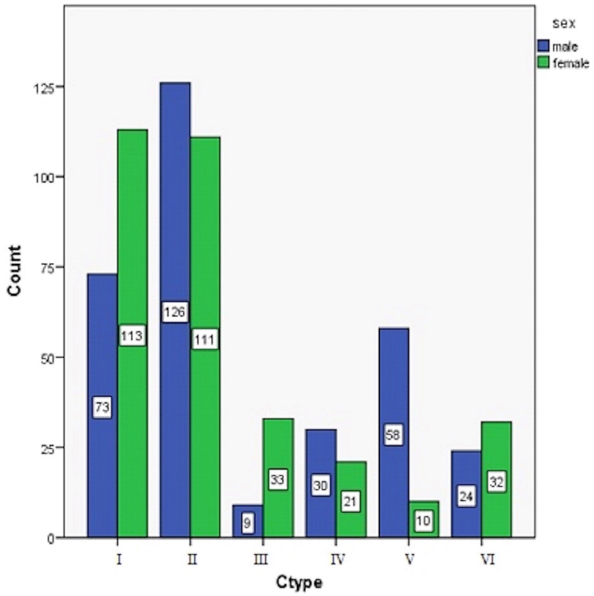

Figure 3. Distribution of coccyx types by sex

When CS, CSS, CD parameters were examined in males, the results of distribution of age by decades was not found to be significant (p>0.05). Absence of fusion in the 2nd decade and presence of bilateral fusion in the 2nd decade in SHF parameter was found to be significant (X^2=13.198; (21), p<0.05). The presence of SLPF parameter on the right side in the 8th decade was significant (X^2=5.648; (21), p<0.05). When the distribution of coccyx types by decades was examined, the presence of type I and VI in the 9th decade and type V in the 8th decade was found to be significant (X^2=7.886; (35), p<0.05).

In males, the individuals in 9th decade in CSL parameter were found to be longer than the individuals in the 2nd and 4th decades, which was significant (p<0.05). In CCI parameter, the individuals in the 9th decade were found to be higher than the individuals in 4th, 5th, 6th, 7th and 8th decades (p<0.05). In CDA parameter, the individuals in the 9th decade were found to be higher than the individuals in 3rd, 4th, 5th, 6th, and 8th decades, which was significant (p<0.05). No significant difference was found between decades in other parameters (p>0.05) (Table 4).

LR analysis was conducted to find out whether the measured parameters had any effect on sex. Enter method was applied and last category was taken as the reference category. Accuracy rate was found to be 96.4% for sex estimation in LR model (n=640, R^2=0.69 (Cox-Snell), R^2=0.92 (Nagelkerke), model: X^2=747.471; (27), p<0.001) (Table 5, 6).

Since no significant accuracy was found when age was grouped in decades, both females and males aged ≥60 years were analysed in two groups (Table 7, 8). LR was conducted with enter method to determine whether the measured parameters in females had an effect on age. In LR model, accuracy rate in age prediction was found to be 76.4% (n=320, R^2=0.29 (Cox-Snell), R^2=0.39 (Nagelkerke), model: X^2=110.725; (19), p<0.001) (Table 7) (Supplementary 1, 2).

Table 3. Measurement results of the parameters analysed in terms of decades in females (n=320)

Parameters	2nd Decade (n=40)	3rd Decade (n=40)	4th Decade (n=40)	5th Decade (n=40)	6th Decade (n=40)	7th Decade (n=40)	8th Decade (n=40)	9th Decade (n=40)
CSL	2.71 (1.74-4.17)	2.66 (1.37-4.00)	2.85 (1.61-4.09)	2.98 (1.81-4.04)	2.60 (1.48-4.05)	2.99 (1.86-4.45)	2.83 (1.83-4.44)	2.91 (1.68-4.21)
CCL	3.26 (1.84-4.86)	2.88 (2.10-4.31)	3.11 (1.51-4.55)	3.26 (1.69-5.13)	2.85 (1.56-4.16)	2.97 (1.76-5.39)	2.94 (1.99-4.59)	2.85 (1.85-4.44)
CT	0.79 (0.58-0.99)	0.81 (0.66-1.06)	0.84 (0.61-1.18)	0.82 (0.57-1.28)	0.81 (0.66-1.23)	0.82 (0.60-1.16)	0.83 (0.58-1.13)	0.85 (0.65-1.18)
CA	2.10 (1.05-3.69)	2.20 (1.42-3.41)	2.54 (1.33-4.66)	2.58 (1.18-3.96)	2.24 (1.29-3.55)	2.32 (1.40-3.57)	2.19 (1.17-3.35)	2.31 (1.31-3.52)
SJA	19.5 (7.0-72.1)	19.3 (5.7-56.7)	20.0 (7.1-76.7)	19.2 (8.7-63.5)	20.9 (5.2-41.6)	21.1 (10.7-55.8)	18.9 (6.5-52.1)	15.1 (5.6-35.7)
IJA	43.8 (10.9-78.9)	42.4 (11.2-82.2)	43.4 (9.8-84.6)	36.5 (9.6-89.2)	29.0 (10.7-92.6)	30.7 (12.7-69.9)	32.1 (8.33-74.7)	32.6 (9.12-63.6)
CCI	91.9 (46.4-133.5)	89.8 (50.7-126.7)	96.5 (50.3-141.7)	90.4 (61.4-127.8)	96.4 (38.9-202.8)	95.2 (62.1-140.1)	94.5 (66.8-165.9)	104.5 (63.6-142.2)
CW	3.17 (1.90-4.32)	2.99 (2.12-4.11)	3.07 (2.10-4.18)	2.86 (2.07-4.17)	2.90 (1.84-4.34)	2.71 (1.76-4.15)	2.82 (1.44-4.31)	2.61 (1.88-4.36)
CDA	5.66 (0-38.50)	4.51 (0-18.10)	5.75 (0-18.10)	4.92 (0-24.8)	5.92 (0-23.80)	6.65 (0-26.90)	4.97 (0-20.30)	5.57 (0-38.5)

CSL: coccyx straight length, CCL: coccyx curvature length, CT: coccyx thickness, CA: coccyx area, SJA: sacrococcygeal joint angle, IJA: intercoccygeal joint angle, CCI: coccyx curvature index, CW: coccyx width, CDA: coccyx deviation angle

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Table 4. Measurement results of the parameters analysed in terms of decades in males (n=320)

Parameters	2nd Decade (n=40)	3rd Decade (n=40)	4th Decade (n=40)	5th Decade (n=40)	6th Decade (n=40)	7th Decade (n=40)	8th Decade (n=40)	9th Decade (n=40)
CSL	3.22 (2.13-5.50)	3.49 (1.97-5.34)	3.33 (0.97-5.45)	3.42 (1.63-5.78)	3.46 (2.33-5.81)	3.62 (2.07-6.08)	3.47 (1.94-4.92)	4.01 (2.04-5.86)
CCL	3.72 (2.24-6.78)	3.72 (2.22-6.41)	3.89 (0.77-6.43)	4.10 (2.09-6.56)	4.04 (2.37-7.27)	4.09 (2.66-7.29)	4.07 (2.32-5.49)	4.50 (2.16-6.20)
CT	1.02 (0.80-1.38)	1.04 (0.70-1.33)	1.03 (0.76-1.36)	1.05 (0.49-1.43)	1.03 (0.74-1.31)	1.04 (0.63-1.52)	1.03 (0.77-1.39)	1.03 (0.77-1.43)
CA	2.90 (1.43-5.17)	3.28 (1.67-6.01)	3.15 (0.96-7.35)	3.35 (1.71-5.00)	3.50 (2.08-6.20)	3.44 (1.86-7.07)	3.51 (1.98-5.38)	3.72 (1.32-6.03)
SJA	15.4 (2.7-57.8)	14.7 (1.9-69.2)	14.1 (3.4-45.1)	11.5 (3.8-49.4)	17.5 (3.26-55.86)	11.5 (2.67-36.0)	14.0 (5.4-39.8)	15.6 (3.78-72.67)
IJA	37.3 (4.4-97.2)	38.0 (5.6-131.8)	35.9 (0.114.3)	49.4 (5.3-103.6)	35.8 (9.4-76.7)	40.7 (10.2-88.0)	44.0 (6.9-99.4)	35.9 (11.0-79.2)
CCI	88.6 (69.8-98.8)	89.3 (72.2-121.6)	88.8 (68.3-125.9)	86.0 (63.1-100.9)	85.2 (74.1-105.9)	84.5 (66.9-97.1)	87.4 (64.5-98.4)	92.9 (76.6-100.0)
CW	3.44 (1.77-5.30)	3.48 (2.50-5.87)	3.53 (2.22-5.80)	3.55 (1.89-5.70)	3.64 (2.62-5.58)	3.47 (2.14-5.77)	3.62 (2.27-5.34)	3.88 (2.34-7.06)
CDA	14.85 (4.33-34.40)	12.00 (1.50-25.50)	13.00 (2.66-61.60)	9.74 (2.25-37.70)	12.85 (4.58-37.80)	14.30 (4.76-40.50)	11.25 (3.29-36.90)	22.35 (5.31-56.00)

CSL: coccyx straight length, CCL: coccyx curvature length, CT: coccyx thickness, CA: coccyx area, SJA: sacrococcygeal joint angle, IJA: intercoccygeal joint angle, CCI: coccyx curvature index, CW: coccyx width, CDA: coccyx deviation angle

Table 5. Logistic Regression model predicting the measured parameters

Parameters	B	S.E.	Wald	df	p	Odd's ratio
CSL	-8.05	2.30	12.15	1	**.000**	.00
CCL	4.75	2.02	5.51	1	**.019**	115.73
CT	-16.48	2.47	44.50	1	**.000**	.00
CA	-.09	.55	.03	1	.860	.90
SJA	.00	.02	.01	1	.911	1.00
IJA	.04	.01	7.73	1	**.005**	1.04
CCI	.29	.08	13.24	1	**.000**	1.34
CW	-2.08	.46	20.05	1	**.000**	.12
CDA	-.50	.06	55.32	1	**.000**	.60
Age	.04	.01	11.47	1	**.001**	1.04
Coccyx type			37.32	5	**.000**	
Type I	-4.79	1.08	19.67	1	**.000**	.01
Type II	-6.55	1.26	26.81	1	**.000**	.00
Type III	-2.37	1.41	2.80	1	.094	.09
Type IV	-6.25	1.42	19.27	1	**.000**	.00
Type V	-7.92	1.40	31.72	1	**.000**	.00
CS			11.18	2	**.004**	
3	-4.74	1.49	10.03	1	**.002**	.01
4	-3.23	1.32	5.97	1	**.014**	.04
CSS			13.66	3	**.003**	
1	3.90	1.71	5.19	1	**.023**	49.39
2	4.67	1.29	13.05	1	**.000**	107.69
3	4.19	1.23	11.51	1	**.001**	66.46
Constant	10.02	7.72	1.68	1	.195	22464.28

p<0.05, S.E: Standart Error, df: Degree of Freedom, CSL: coccyx straight length, CCL: coccyx curvature length, CT: coccyx thickness, CA: coccyx area, SJA: sacrococcygeal joint angle, IJA: intercoccygeal joint angle, CCI: coccyx curvature index, CW: coccyx width, CDA: coccyx deviation angle, CS: coccyx number, CSS: number of coccyx segment

Reliability Analysis

ICC for intra-observer reliability was 0.947 for all quantitative measurements. These results showed almost perfect repeatability.

Table 6. Classification table of Logistic Regression model

Observed		Predicted		
		Sex		Percentage Correct
		Male	Female	
Sex	Male	306	14	95.6
	Female	9	309	97.2
Overall Percentage				**96.4**

Table 7. Classification table of Logistic Regression model in females

Female Observed		Female Predicted		
		Age		Percentage Correct
		20-59	60-99	
Age	20-59	121	38	76.1
	60-99	37	124	76.9
Overall Percentage				**76.5**

Table 8. Classification table of Logistic Regression model in males

Male Observed		Male Predicted		
		Age		Percentage Correct
		20-59	60-99	
Age	20-59	113	47	70.6
	60-99	48	112	70.0
Overall Percentage				**70.3**

Discussion

Practical, accurate and easy methods are used in cases of mass deaths and in cases when deceased individuals are found together. Sex estimation in the identification of dismembered and deformed individuals in cases such as wars, earthquakes and plane accidents reduces the possible identification data by half [17]. Osteometry performed with CT images is a fast and reliable method which allows access to each point of the bone, in which coordinates can be measured, and which can be measured in terms of lengths and angle [5,6]. There is a considerable lack of data about differences in coccyx in terms of sex and age in identification [8].

It may not be possible to determine the morphometry of structures such as angulating coccyx on a single plane [18]. When compared with other studies in literature, the number of coccyx and measurement parameters were higher in our study. While making measurements with CT images, the images were standardized by bringing the image to the orthogonal plane in a 3-plane area. Therefore, the errors resulting from position were minimized. As a result of the reliability analysis in the study, ICC was found to be 0.947, showing almost perfect reliability. CSL, CCL, CT, CA, IJA, CW and CDA parameters were found to be statistically significantly higher in males, while SJA parameter was found to be statistically significantly higher in females. Accuracy rate of sex prediction from coccyx in LR model was found to be statistically significantly higher in males, while it was statistically significantly higher in females in SJA parameter. The accuracy rate of sex prediction from coccyx in LR model was found to be 96.4%.

In previously conducted studies [8,19,20,21], the CSL parameter was measured from the distance between the superior midpoint of the first coccyx vertebra to the inferior midpoint and it was found to be higher in males. Unlike literature, it was measured from the distance between the superior anterior point of coccyx and the inferior anterior point of coccyx. As a result, it was determined that CSL is higher in men than in women using different measurement methods.

Previously conducted studies [15,21] have found CCL parameter to be higher in men. Lee et al. [8] who evaluated the CT, CW, IJA and SJA parameters on 76 women and 60 men found that CT and CW parameters were higher in men, while no significant difference was found between sexes in IJA and SJA parameters. In the present study, SJA parameter was found to be higher in females, while CCL, CT, CW and IJA parameters were found to be higher in males. Bakıcı et al. [15] who measured CA parameter for the first time on 100 individuals did not find significant difference between sexes. In the present study, CA parameter was found to be higher in males. We believe that the difference between the above-mentioned studies and this study stems from the fact that this study included a larger number of individuals and that the distribution between gender groups was equal.

Marwan et al. [22] found that CDA parameter did not show significant results between sexes, while Woon et al. [21] found higher CDA in men. Similarly, CDA was found to be higher in males in this study. Hekimoğlu and Ergun [18] evaluated CD morphologically; however, they did not indicate sex-specific results. In the present study, it was found that CD was not significant in females, while left deviation was significant in males.

In a study conducted in Korea, CCI was found to be higher in men [23]. In the present study, while CCI was found to be higher in women, it was not found to be significant. In their study, Güneri and Güngör [19] found the CS parameter to be lower in women. In the present study, no significance was found between sexes in CS. In studies examining the CSS parameter [22,23], no significant difference was reported between sexes. In the present study, the result that there were two segments in women and one, three and four segments in men in CSS was found to be significant. We believe that these results were due to the fact that the studies were conducted in different geographical areas and on different populations.

In their study they conducted on coccyx typing in Turkish population, Karayol et al. [20] found the rates of types from the highest to the lowest as type II, type I, type III, type IV and type V. Hekimoğlu and Ergun [18] reported that the type with the highest frequency was type I, while the type with the lowest frequency was type V, and there were no type IVs. In the

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present study, the most frequent type was type II, followed by type I, type V, type VI, type IV and finally type III. The result that the women had type I and III coccyx, while men had type V coccyx was found to be significant. When studies conducted were reviewed, it was found that no analyses were made in coccyx typing in terms of sex. We believe that our study will be a pioneer in the literature.

Woon et al. [21] reported SLPF to be higher in men when compared with women. In a study conducted in Korean population [8], unilateral and bilateral fusion of SLPF was higher in men and bilateral fusion of SHF was higher than unilateral fusion. In this study, it was significant that SLPF fusion was not found in females, while it was bilateral in males. It was also found that SHF did not differ according to sex. We think that the different results between the studies may be due to population differences.

Marwan et al. [22] who measured CSL and CCL parameters could not find a significant result when individuals younger than 50 and those older than 50 were compared. In the present study, in terms of decades, no significant difference was found between men and women in CCL parameter. However, in terms of CSL parameter, it was found that the individuals in the 9th decade had longer values than individuals in the 2nd and 4th decade. Lee et al. [8] measured the CW parameter but did not evaluate among age groups. In our study, when CW parameter was evaluated between age groups of both women and men, no significant difference was found.

The first study that measured the CA parameter in the literature [15] did not evaluate the CA parameter between age groups. In this study, when age was analysed in terms of decades, no significant results were found in both men and women. In a study examining CCI and SJA parameters according to age by decades, it was found that CCI decreased with age and SJA increased with increasing age in both sexes [23]. In this study, no difference was found in SJA in both sexes when analysed in terms of decades. No significant difference was found in CCI parameter between age groups in females. However, it was found to be higher in males in the 9th decade than in males in the 4th, 5th, 6th, 7th and 8th decades. We believe that the coccyx deviation disappears as a result of the increase in CSL and CCI in men over time.

Karayol et al. [20] found that CT increased significantly with increasing age and CS increased with increasing CT. In this study, no significant results were found between age and decades in the CT parameter in both sexes. However, it was found to be significant that the CS parameter was 3 in the 7th and 9th decades and 4 in the 2nd decade in women. Yoon et al. [23] found a weak negative correlation between CSS parameter and age. In this study, no significant results were found between decades in men, whereas two segments were found to be significant in women in the 8th decade. We think that this difference in women may be caused by pregnancy and postmenopausal osteoporosis.

In studies conducted in Arab and Korean populations, CDA and CD parameters did not differ between sex and age groups [8, 22]. In the present study, no significant difference was found between the groups in CDA and CD in females and CD in males. In males, CDA was found to be significantly higher only in individuals in the 9th decade compared to individuals in the 3rd, 4th, 5th, 6th and 8th decades. Our study is the first study to evaluate coccyx deviation both morphometrically and morphologically between sexes and age groups in the Turkish population. We think that it may be helpful for future studies on this subject.

In the literature, there is a study [8] indicating that the IJA parameter did not change in both sexes in individuals under and over 50 years of age. Przybylski et al. [25] analysed individuals over 20 years of age in four groups with an interval of 20 years and found that the IJA parameter was wider in women than in men and that the IJA parameter showed a negative correlation with age. In the present study, the individuals between 20 and 99 years of age were compared between sexes in terms of decades. It was found that the IJA parameter was larger in males and smaller in females in the 6th decade compared to those in the 2nd and 4th decades. We believe that the results obtained may be helpful in the research of idiopathic coccidine.

Woon and Stringer [26] found that SHF was not correlated with age and sex. Lee et al. [8] found that SHF and SLPF did not differ significantly between young and old groups of the same sex. In this study, it was found that SHF was significant in women if there was no fusion or bilateral fusion in the 3rd decade and left fusion in the 4th decade. In men, it was found that the absence of fusion in the 2nd decade and bilateral fusion in the 9th decade was significant. In the SLPF parameter, no significant result was found in females, but its presence on the right side was found to be significant in males in the 8th decade. We think that these differences in the results with the advancement of age may be due to the position associated with fusion or sitting over time after coccyx deviations as a result of traumatised situations such as falls, and heavy working conditions in the past.

When coccyx typing was analysed between decades, it was found that type I coccyx increased significantly in the 8th, 9th and 10th decades compared to the averages in other decades [23]. In the present study, no significant difference was found between decades in females. However, the presence of type I and VI in the 9th decade and type V in the 8th decade was significant in men.

In previous sex predictions using sacrococcygeal morphometry, Elkhateeb et al. [27] reported an accuracy rate of 68.9% and Zhan et al. [28] reported an accuracy rate of 84.9%. To the best of our knowledge, there is no study on sex prediction using only coccyx. In the present study, a high and reliable sex prediction rate of 96.4% was reached by using only coccyx.

To our knowledge, there are no studies in the literature that estimate age solely through the coccyx and compare coccyx parameter data between more than two age groups and between older and younger groups. In the present study, when age groups were analysed in two groups, high and reliable results were obtained in both women and men. Coccyx parameters between older and younger individuals were compared in two groups. It was found that coccyx changed by 70-76% in older individuals compared to younger individuals due to causes such as osteoporosis and degeneration.

The limitations of our study include lack of information on personal factors such as height, weight, obesity and body mass index, as well as environmental and genetic factors. Additionally, since our population is limited to a specific geographical region, results may vary in different regions. Since individuals could not be followed up over the long term, the effects of changes over time could not be assessed on an individual basis.

Conclusion

The strengths of this study are that the study group was relatively large, the number of men and women was equal, the differences between sexes were examined and evaluated according to age groups, the effect of age on sex was investigated, reliable methodology was used, and predictions were made between sex and age groups for the first time through the coccyx. Significant and reliable results were found between sexes and between different age groups. We believe that the present study may be a pioneer in the literature for future studies that will make age and sex prediction.

Conflict of Interests
The authors declare that there is no conflict of interest in the study.

Financial Disclosure
The authors declare that they have received no financial support for the study.

Ethical Approval
Approval was obtained from the ethics committee of İzmir Bakırçay University. The procedures used in this study adhere to the tenets of the Declaration of Helsinki. (Reference Number: 1085/2023).

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