ORIGINAL ARTICLE

MRI-based detailed evaluation of the anatomy of the human coccyx among Turkish adults

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Abstract

Aim: The human coccyx varies considerably in shape and size. The objective of this study was to investigate the morphology and morphometry of the coccyx on pelvic magnetic resonance imaging in asymptomatic individuals among Turkish adults.

Materials and Methods: This study was conducted retrospectively on the pelvic magnetic resonance images of 456 adult patients without a history of trauma in the coccyx region. The coccygeal vertebrae count, number of bone segments, and intercoccygeal and sacrococcygeal joint fusions were determined from the sagittal plane images. In addition, the length and angles (the sacrococcygeal angle, intercoccygeal joint angle, and sacrococcygeal joint angle) were measured.

Statistical Analysis Used: Data were analyzed using the *T*-test or Mann-Whitney *U*-test, the ANOVA, or Kruskal-Wallis tests, and the chi-square test was used for the categorical variables.

Results: The coccyx is formed by four, five, or three vertebrae in a decreasing ratio. The coccyx is composed of one to five bone segments; one bone segment was found in 2.8% of the cases. Intercoccygeal joint fusions been observed predominantly in the last intercoccygeal joint, with or without sacrococcygeal joint fusion. The coccyx was found to be longer in adult males than in adult females. The sacrococcygeal angle might be anteverted or retroverted.

Conclusion: The findings are contrary to the conventional knowledge in that the vertebrae shaping the coccyx were completely fused and consisting of a single bone in very few cases. Better understanding of the anatomical variation of the coccyx may be useful for clinicians evaluating patients presenting with conditions in the coccygeal region.

Key words: Coccyx, morphology, morphometry, sacrum

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Introduction

The word coccyx originates from "cuckoo," which is the name of the cuckoo bird in Greek.[1] The name of the coccyx is hypothesized to be derived from its similarity in appearance to the beak of the cuckoo. The coccyx is a triangular bone forming the last part of the vertebral column and is formed from the merger of the last four rudimentary vertebrae.[2-4] It consists of the residue of three to five vertebrae.[2] The first

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rudimentary vertebra is the largest; it articulates with the distal portion of the sacrum and is, in some cases, observed to be fused. The size of the next coccygeal vertebra is smaller and ends in the form of a nodule at the bottom. The coccyx is directed downward and forward from the sacral apex. The pelvic face is inclined upward and forward, and the rear face is inclined downward and backward.

The cocygeal segment represented 0.4% of the weight of the entire column.[5] The coccyx consists of small bone segments that are separated with rudimentary intervertebral disks (the intercoccygeal joints) or fused with each other. Postacchini and Massobrio[6] discussed the importance of revealing the anatomical features prior to medical procedures performed on the coccyx and developed a radiologic classification of the coccyx based on roentgenographic examinations. An identical classification was developed later by Kerimoglu *et al.*,[7] Przybylski *et al.*,[8] and Marwan *et al.*[9] using CT imaging and by Woon *et al.*[10] using magnetic resonance imaging (MRI). Postacchini and Massobrio[6] reported that individuals are predisposed to coccygodynia in cases in which the ventral angulation of the coccyx is increased and in the presence of anterior subluxation in the sacrococcygeal or first intercoccygeal joint. Similarly, Woon *et al.*[10] reported that patients in whom the coccyx curled extremely to the ventral side with reduced intercoccygeal fusion were predisposed to coccygodynia. In recent years, studies conducted in asymptomatic patients[7,9,11] have presented information on coccyx morphology as well as morphometric measurements, such as the segment number, length and angulation of the coccyx, and possible anatomical differences.

The objective of this study was to investigate the morphology and morphometry of the coccyx by pelvic MRI in asymptomatic individuals. We evaluated the number of vertebrae and the number of segments and intercoccygeal joint fusions, and we aimed to compare our results with the results of earlier studies on this subject.

Materials and Methods

Our study was conducted on individuals without a history of coccygeal pain or trauma and whose pelvic MRIs were performed for other reasons in the Department of Radiology of the Mugla Sıtkı Kocman University Education and Research Hospital between August 2013 and December 2014; approval for this study was obtained from the ethics committee (Ethics Committee of Mugla Sitki Kocman University, Mugla, Turkey, decision number: 52/19.03.2015). Four hundred fifty-six patients between 18 and 97 years of age (122 male, 334 female) examined for the anatomy of the coccyx through coronal, sagittal, and axial planes of MRI examinations were included in the study. The resulting images were divided into sex (male–female) groups.

For the MR images, 1.5-T scanners (GE 1.5 Signa HDxt MRI scanner, GE Healthcare, Wisconsin) were used. The sagittal images were used for the evaluation of the morphometric parameters. The coronal, sagittal, and axial images were used for the morphologic evaluation. The T2-weighted images were obtained with TR 3520, TE 130, NEX 2, and a slice thickness of 4 mm. Then, the images were transferred to the workstation (Syngo VIA console, Siemens). The measurements were made with the aid of these images. All of the measurements were obtained by two experienced radiologist and orthopedist. Intra/interobserver variability for the measurements was determined at less than 5%. The following measurements and evaluations of the coccyx were constructed from the images: the number of vertebrae in the coccyx and the number of segments in the coccyx (in case of articulation of the first coccygeal vertebra with the fifth sacral vertebra, this vertebra was considered a separate bone segment). The intercoccygeal and sacrococcygeal joint fusions were determined. The straight length of the coccyx was measured as the distance between the middle point of the upper edge of the first coccygeal vertebra and the apex of the coccyx [Figure 1a]. The sacrococcygeal angle was measured as the angle formed when the line between the midpoint of the upper edge of the first sacral vertebra and the midpoint of the first coccygeal vertebra was crossed with the line between the apex of the coccyx and the midpoint of the first coccygeal vertebra [Figure 1b]. The sacrococcygeal joint angle was measured as the angle between the axial axis of the fifth sacral vertebra and the first coccygeal vertebra [Figure 1c and d]. The intercoccygeal joint angle was measured as the angle between the axial axis of the first coccygeal vertebra and the subsequent vertebrae [Figure 1e].

The data of our study were created with SPSS 20.0 software. For the evaluation of the data, the Kolmogorov-Smirnov and Shapiro-Wilk tests were used for the distribution of normality tests; parametric tests were used for the normally distributed variables, and nonparametric tests were used for the variables that were not normally distributed. The *T*-test or Mann-Whitney *U*-test was used for the significance test of the difference between the two means, and the ANOVA or Kruskal-Wallis test was used for the comparison of more than two means. The chi-square test was used for the categorical variables. The measurements were compared for both intra-observer and interobserver agreements using Pearson's correlation test. Our data are presented in the tables as the arithmetic mean ($\bar{X}$), the standard error (SE), the number of individuals (n), and the percentage (%); the statistical significance was considered as P less than 0.05.

Results

In our study, a total of 456 MRIs were evaluated, and the measurements were obtained in the sagittal plane. One

hundred twenty-two of these individuals (26.8%) were males and 334 (73.2%) were females. The average age of the subjects was 43.9 years. The average age of males and females was 45.7 years (minimum 18, maximum 97) and 43.2 years (minimum 18, maximum 84), respectively. Intra/interobserver variability for the measurements was determined at less than 5%.

The Number of Vertebrae

The coccyx consisted of three, four, and five vertebrae in 10 (8.2%), 98 (80.3%), and 14 (11.5%) of the 122 males, respectively, and in 37 (11.1%), 253 (75.7%), and 44 (13.2%) of the 334 females, respectively. There was no difference between the male and female individuals in the number of vertebrae ($P = 0.558$). The distribution of the number of vertebrae forming the coccyx by sex is presented in [Table 1].

Fusion Levels

The sacrococcygeal fusion was found in 23.8 and 21.6% of males and females, respectively. There were no differences between males and females in the incidence of sacrococcygeal joint fusion. As the number of vertebrae increased, the frequency of fusion in the sacrococcygeal joint increased in both sexes [Table 2].

The intercoccygeal fusion was found at different levels between the vertebrae forming the coccyx, with or without the sacrococcygeal joint fusion. The observed intercoccygeal joint fusion in males was 85.2% [Table 3]. There were two fusions in both first and last intercoccygeal joint in five male patients in whom coccyx were formed by four vertebrae. The observed intercoccygeal joint fusion in females was 82.9% [Table 4]. In 10 female patients, two fusions in intercoccygeal joints were observed [Table 4]. Fusion in those with three vertebrae was less observed than in those with four and five vertebrae for both sexes (40.0% in males and 64.9% in females). The rates of fusion in males and females according to the number of vertebrae are shown in [Table 3 and Table 4], respectively. As the number of vertebrae increased, the frequency of fusion in the intercoccygeal joints increased. The fusion rates in the first intercoccygeal joint were less in both sexes. Fusion in those with three and four vertebrae was observed predominantly in the last intercoccygeal joint (Cx2-Cx3 and Cx3-Cx4, respectively) [Figure 2a and b]. Fusion was frequently observed at the level of Cx3-Cx5 and Cx3-Cx4 in those with five vertebrae

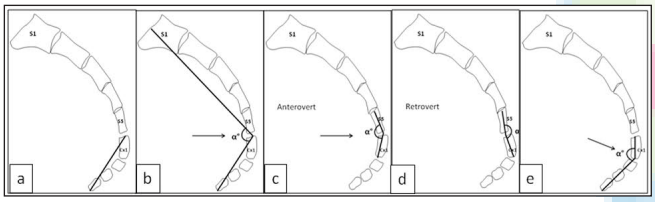

Figure 1: Measurement methodology. (a) The straight coccyx length. (b) The sacrococcygeal angle. (c and d) The anteverted and retroverted sacrococcygeal joint angle. (e) The intercoccygeal joint angle. *S1* is the first sacral vertebra. *S5* is the fifth sacral vertebra. *Cx1* is the first coccygeal vertebra

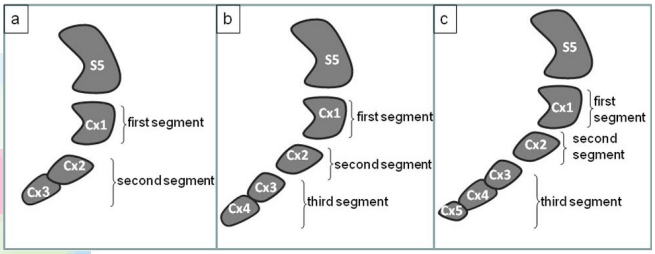

Figure 2: The most common levels of fusion. (a) Coccyx consisting of three vertebrae and two bone segments. (b) Coccyx consisting of four vertebrae and three bone segments. (c) Coccyx consisting of five vertebrae and three bone segments. S5 is the fifth sacral vertebra. Cx1 is the first coccygeal vertebra. Cx2 is the second coccygeal vertebra. Cx3 is the third coccygeal vertebra. Cx4 is the fourth coccygeal vertebra. Cx5 is the fifth coccygeal vertebra

Table 1: The number of vertebrae forming the coccyx by sex

	The number of vertebrae						Total, *n* (%)
	3		4		5		
	N	%	*N*	%	*N*	%	
Male	10	8.2	98	80.3	14	11.5	122 (100)
Female	37	11.1	253	75.7	44	13.2	334 (100)
Total	47	10.3	351	77	58	12.7	456 (100)

Table 2: The sacrococcygeal fusion by sex and the number of vertebrae

The number of vertebrae	Male, *n* (%)	The number of vertebrae	Female, *n* (%)
3 (n = 10)	2 (20.0)	3 (n = 37)	3 (8.1)
4 (n=98)	23 (23.5)	4 (n = 253)	51 (20.2)
5 (n=14)	4 (28.6)	5 (n = 44)	18 (40.9)
Total (*n* = 122)	29 (23.8)	Total (*n* = 334)	72 (21.6)

Table 3: Males: fusion level based on the number of vertebrae

		The number of vertebrae						
		3 (n = 10)		4 (n = 98)		5 (n = 14)	Total (n = 122)	
		N	%	*N*	%	*N*	%	*N* (%)
Fusion level	No fusion	6	60.0	10	10.2	2	14.3	18 (14.8)
	Fusion	4	40	88*	89.8	12	85.7	104* (85.2)
	Cx1--Cx2	0	0	5	5.1	0	0	5 (4.1)
	Cx2--Cx3	4	40.0	3	3.1	0	0	7 (5.7)
	Cx1--Cx3	0	0	0	0	0	0	0 (0.0)
	Cx2--Cx4	--	--	32	32.7	0	0	32 (26.2)
	Cx3--Cx4	--	--	51	52.0	1	7.1	52 (42.6)
	Cx1--Cx4	--	--	1	1.0	0	0	1 (0.8)
	Cx2--Cx5	--	--	--	--	3	21.4	3 (2.5)
	Cx3--Cx5	--	--	--	--	5	35.7	5 (4.1)
	Cx4--Cx5	--	--	--	--	3	21.4	3 (2.5)
	Cx1--Cx5	--	--	--	--	0	0	0 (0.0)
	Full fusion	0		1	1.0	0	0	1 (0.8)

S5 is the fifth sacral vertebra., Cx is the coccygeal vertebra., *There are two intercoccygeal joint fusion in five males in whom coccyx were formed by four vertebrae.

Table 4: Females: fusion level based on the number of vertebrae

		The number of vertebrae						
		3 (n = 37)		4 (n = 253)		5 (n = 44)	Total (n = 334)	
		N	%	*N*	%	*N*	%	*N* (%)
Fusion level	No fusion	13	35.1	40	15.8	4	9.1	57 (17.1)
	Fusion	24	64.9	213*	84.2	40**	90.9	277*** (82.9)
	Cx1--Cx2	1	2.7	8	3.2	1	2.3	10 (3.0)
	Cx2--Cx3	20	54.1	21	8.3	2	4.5	43 (12.9)
	Cx1--Cx3	2	5.4	0	0	0	0	2 (0.6)
	Cx2--Cx4	--	--	100	39.5	2	4.5	102 (30.5)
	Cx3--Cx4	--	--	83	32.8	1	2.3	84 (25.1)
	Cx1--Cx4	--	--	6	2.4	0	0	6 (1.8)
	Cx2--Cx5	--	--	--	--	10	22.8	10 (3.0)
	Cx3--Cx5	--	--	--	--	17	38.6	17 (5.1)
	Cx4--Cx5	--	--	--	--	10	22.8	10 (3.0)
	Cx1--Cx5	--	--	--	--	0	0	0 (0.0)
	Full fusion	1	2.7	2	0.8	0	0	3 (0.9)

S5 is the fifth sacral vertebra., Cx is the coccygeal vertebra., *There are two intercoccygeal joint fusion in seven females in whom coccyx were formed by four vertebrae., **There are two intercoccygeal joint fusion in three females in whom coccyx were formed by five vertebrae., ***There are two intercoccygeal joint fusion in 10 females.

[Figure 2c]. Fusion of the sacrococcygeal joint and fusion of all the intercoccygeal joints (full fusion) were identified in four cases, including one male and three females. As a result of the statistical analysis, the incidence of fusion between Cx2-Cx3 vertebrae was found to be greater in females (P = 0.031).

The Number of Segments

Group of fused vertebrae are termed as a segment as in the previous studies.[6] Our study showed that the coccyx is composed of one to five segments, depending on the number of fusions observed between the vertebrae [Figure 3]. The coccyx was composed of one bone segment in 13 cases (2.8%), two bone segments in 183 cases (40.1%), three bone segments in 192 cases (42.1%), four bone segments in 63 cases (13.8%), and five bone segments in five cases (1.1%) [Table 5]. The number of segments was evaluated by the number of vertebrae; the possibility of two segments was found to be higher in those with three vertebrae than in others (P = 0000). The possibility of two or three segments was higher in those with four and five vertebrae (P = 0.000). There was no statistically significant relationship between males and females in terms of the number of segments (P = 0.09).

Table 5: The number of coccyx segments according to the number of vertebrae

The number of vertebrae			Male, *n*	Female, *n*	Total, *n* (%)*
3	The number of segments	1	0	3	3 (6.4)
		2	4	21	25 (53.2)
		3	6	13	19 (40.4)
4	The number of segments	1	2	8	10 (2.8)
		2	36	107	143 (41)
		3	50	99	149 (42.1)
		4	10	39	49 (14)
5	The number of Segments	1	0	0	0 (0)
		2	3	12	15 (25.8)
		3	5	19	24 (41.3)
		4	4	10	14 (24.1)
		5	2	3	5 (8.6)

*Within their own groups.

Table 6: Angle according to sex

	Sacrococcygeal angle (°)		Sacrococcygeal joint angle (°)				Intercoccygeal angle (°)	
			Anteverted		Retroverted			
	Mean ± SE	Range	Mean	Range	Mean	Range	Mean ± SE	Range
Male	111 ± 1.18	63--146	166	96--180	173	179--160	134 ± 1.71	83--180
Female	105 ± 0.82	64--147	158	96--180	171	178--152	135 ± 1.15	77--180
Total	107 ±0.69	63--147	160	96--180	172	152--179	135 ± 1.15	77--180

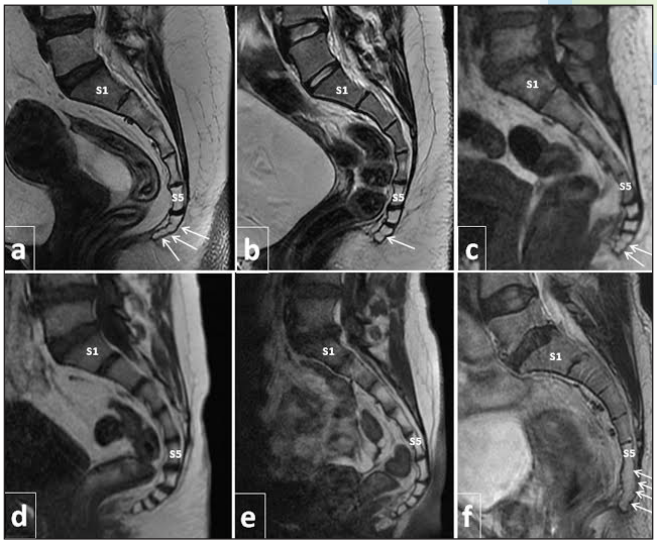

Figure 3: Segments of the coccyx. (a) In a 46-year-old female patient, all the intercoccygeal joints were fused. (b) In a 25-year-old female patient, the last intercoccygeal joint was fused. (c) In a 50-year-old female patient, the last intercoccygeal joints were fused. (d) In a 25-year-old male patient, no fusion was observed in the intercoccygeal joint. (e) In a 27-year-old female patient, no fusion was observed in the intercoccygeal joint. (f) In a 59-year-old male patient, all the intercoccygeal joints and the sacrococcygeal joint were fused (full fusion). White arrow indicates a fused intercoccygeal joint. S1 is the first sacral vertebra. S5 is the fifth sacral vertebra

The Length of the Coccyx

The average length of the coccyx was 35.6 mm, and the average length for males and females was 38.5 ± 0.59 mm (minimum 22.2, maximum 56.2) and 34.5 ± 0.41 mm (minimum 19.5, maximum 60.8), respectively. The coccyx was found to be longer in males than in females ($P = 0.000$). In the cases in which the number of vertebrae was three, four, or five, the average length of the coccyx was 28.75 ± 0.82, 35.61 ± 0.38, and 40.72 ± 0.91 mm, respectively. The length increased with the increase in the number of vertebrae forming the coccyx ($P = 0.000$).

Sacrococcygeal angle, sacrococcygeal joint angle, and intercoccygeal angle

The average sacrococcygeal angle was 107° ± 0.69° (111° in males, 105° in females). The sacrococcygeal angle was significantly higher in males than in females ($P = 0.000$). There was no difference in the sacrococcygeal angle in terms of the number of vertebrae and segments ($P > 0.05$).

The sacrococcygeal joint angle was retroverted in 39 cases (males 16; females 23) and anteverted in other cases. Whereas the average angle was 160° in the anteverted angles, the average angle was 172° in the retroverted angles. This angle was greater in males than in females under both conditions ($P = 0.000$).

The intercoccygeal angle was 135° ± 1.15° (134° in males, 135 in females). There was no significant difference between males and females ($P = 0.595$). However, the intercoccygeal angle varied in terms of the number of segments. This angle was significantly greater in the coccyges with a single segment than in those with two, three, or four segments and significantly greater in the coccyges with two or three segments than in those with four segments ($P < 0.05$). The angle values are summarized by sex in [Table 6].

Discussion

In recent years, anatomical studies of the coccyx using radiologic imaging procedures in patients with coccydynia have been outstanding.[6,7,10,12] Fewer studies have been conducted on normal adult coccyx morphology and morphometry.[8,9,11] Whereas the number of segments comprising the coccyx was reported in these studies, the number of vertebrae was not mentioned. The results of this study indicated that each vertebra forming the coccyx could be considered a separate bone separated by an intercoccygeal joint. Additionally, two or more of these bones could be perceived as being fused. In this study, each new piece of bone was described as a "segment," with the condition that fused pieces of bone were considered as one segment.

In our study, the coccyx was formed from four vertebrae in 77% of the cases, from five vertebrae in 12.7%, and from three vertebrae in 10.3%. There was no significant relationship between the number of vertebrae and sex.

The coccyx consists of small bone segments separated by rudimentary intervertebral disks (intercoccygeal joints) or fused together.[6] There are disks between the segments as in other regions of the vertebral column.

Studies of the anatomy of the coccyx have shown that it typically consists of one to five segments.[6,8,9] Classic books state that the coccyx consists of vertebrae fused together.[14] Postacchini and Massobrio[6] reported that all vertebrae are fused in 7% of asymptomatic cases and 8% of the cases with coccydynia. Whereas Przybylski *et al.*,[8] in their series with 500 cases, stated that the coccyx was found to be a single bone in only one case, Marwan *et al.*[9] reported no case in their series with 202 cases. In our study, the formation of the coccyx through the fusion of all vertebrae was observed only in 2.8% of the cases.

In their study of 120 asymptomatic cases, Postacchini and Massobrio [6] showed that the coccyx consisted of two bone segments separated by intervertebral disks in 54% of the cases, three bone segments separated by two intercoccygeal joints in 34%, and four bone segments separated by three intercoccygeal joints in 5%. These results demonstrated that the coccyx predominantly consisted of two or three segments.[6] Our study showed that one to five segments shaped the coccyx, predominantly, two segments (40.1%) or three (42.1%) segments. There was no significant relationship between the number of segments and sex. The number of segments increased with the increase in the number of vertebrae in parallel with the increase in the incidence of intercoccygeal joint fusion. In results similar to our findings, three segments were found more frequently in previous studies on this subject.[8,9]

The rates of sacrococcygeal and intercoccygeal joint fusion vary among studies.[6,9,11] Sacrococcygeal joint fusion resulting from the merger of the fifth sacral vertebra with the first coccygeal vertebra was found in 22.1% of the cases (in 23.8% of males and 21.6% of females) in our study. The cases with full fusion were not included in this rate. There were no differences between males and females in the incidence of sacrococcygeal joint fusion. An increase in the rate of fusion is observed with an increase in the number of vertebrae.

Intercoccygeal joints might form one or more segments by merging. This fusion was found to be most common at the level of the last intercoccygeal joints, which are Cx2-Cx3 in cases with three vertebrae, Cx3-Cx4 in cases with four vertebrae, and Cx3-Cx5 in cases with five vertebrae. These fusions were observed predominantly in the last intercoccygeal joints regardless of the number of vertebrae. In 2.8% of the cases in our study, the coccyx became a single bone because all the intercoccygeal joints were fused. In four (0.9%) of those cases, sacrococcygeal joint fusion was also observed. Intercoccygeal joint fusion has been reported most frequently in the second and third intercoccygeal joints in other studies, similar to our results.[6,9-11]

The morphometric findings of our cases showed that the straight length of the coccyx was lengthier in males than in females. This finding was in agreement with the three studies conducted previously.[8,9,11] Woon *et al.*[11] did not find a significant relationship between the coccyx length with the height, age, and BMI of the subjects. In their study on Arabs, Marwan *et al.*[9] reported that the length of the coccyx was longer in young individuals than in older ones. According to the results of our study, the length of the coccyx increased with an increase in the number of vertebrae forming the coccyx, and the increase was statistically significant.

The sacrococcygeal joint is typically a symphysis-type joint that forms between the sacral apex and the base of the coccyx. A fibrocartilaginous disk is located in the joint cavity. In some cases, the coccyx is more mobile, and the joint is synovial. In previous studies,[9,11] the sacrococcygeal joint angle was measured as the angle between the long axis of the S5 and the Cx1 vertebrae. In all three studies, this angle was greater in males. However, the front and rear angulation of the angle was not mentioned in these studies. Whereas this angle was found to be retroverted in 39 of our

cases, it was found to be anteverted in other individuals. The sacrococcygeal joint angle was found to be greater in males than in females, in those individuals showing both anteverted and retroverted angulation.

Kim and Suk[13] reported that radiologic measurement of the intercoccygeal angle was a useful method for revealing a coccyx angle deformity. In our study, we measured the intercoccygeal angle as the angulation between the first coccygeal vertebra and the axial planes of subsequent vertebrae. The findings in our cases show that the sacrococcygeal angle and sacrococcygeal joint angles are greater in males and that the intercoccygeal angle is greater in females. In three previous studies, the sacrococcygeal angle and sacrococcygeal joint angle were found to be greater in males,[9-11] and Marwan *et al.*[9] found that the intercoccygeal angle is greater in females.

The presacral region involve several different anatomical structure and related pathologic condition.[14] Sacrococcygeal fusion is an obstetrical problem.[15] The posterior sagittal diameter of the outlet of the pelvimetric analysis is important.[15] Sacral-coccygeal fusion may contribute to shortening of posterior sagittal diameter. Females with sacrococcygeal fusion were found to have a shorter posterior sagittal diameter of outlet compared with those without sacrococcygeal fusion.[15] The findings of the current study may help us to better understand pelvic morphometry.

There are some limitations of our study. This study made an effort to specify bony characteristics of the coccyx. Our sample size was quite large. However, our data did not include weight, height, and BMI. These features was found to be associated with some morphologic or morphometric parameters of the coccyx in previous studies.[11,12] The current study was limited to Turkish adults.

The findings are contrary to the conventional knowledge in that the vertebrae shaping the coccyx were completely fused and consisted of a single bone in very few cases. Knowledge of these and other morphologic and morphometric changes in the coccyx would be useful to support clinicians' diagnosis and treatment decisions in cases involving the coccygeal region. Knowledge of the anatomical differences of the coccyx would be useful in cases requiring surgical removal of the coccyx.

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Conflicts of interest
There are no conflicts of interest.

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