Araştırma Makalesi / Research Article

Anatomic and morphometric evaluation of the coccyx in the adult population

Erişkin popülasyonda koksiksin anatomik ve morfometrik değerlendirilmesi

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Abstract

Background: To evaluate the sacrococcygeal anatomy and morphometry with lower abdomen magnetic resonance (MR) images in asymptomatic adult subjects
Methods: We retrospectively reviewed the images of 216 adult patients who underwent MR imaging of the lower abdomen for reasons other than coccydynia in the radiology clinic. In this evaluation, coccyx (Co) thickness (from Co1 middle section), sacrococcygeal angle, fusion between vertebrates, number of coccygeal vertebrae, sacrococcygeal joint angle, intercocsigeal joint angle, coccyx type, presence of subluxation, coccyx flat length, coccyx curvature length, sacrum flat length, sacrum curvature length, sacrococcygeal flat length, sacrococcygeal curvature length, sacral angle, coccyx curvature index, sacrum curvature index, sacrococcygeal curvature index were measured.
Results: The mean number of coccyx vertebrae was 3.5 ± 0.75 in females and 3.8 ± 0.78 in males. The mean coccyx thickness was 7.3 ±1.4 mm in females and 8.4±1.8 in males. Subluxation was determined in 59 (27.3%) cases, and not in 157(72.7%) cases. The mean length of the coccyx was 35.4±6.6 mm in females and 38.9±8.7 mm in males. The mean length of the coccyx curvature was 37.5±7.2 mm in females and 41.7±9.1 mm in males.
The most common coccyx type in both males and females was type II coccyx in 98 (45.4%) patients. The sacrococcygeal angle was 109±15 degrees in females and 113±13 in males.
Conclusion: Knowledge of the vertebrae anatomy of asymptomatic patients may prevent unnecessary surgery in coccydynia. Wide ranges of similar studies are needed to be done with patients with coccydynia.

Keywords: Coccyx anatomy, Magnetic resonance imaging, Sacrococcygeal angle, Coccygeal angle

Öz.

Amaç: Sakrokoksigeal anatomi ve morfometrinin asemptomatik erişkin bireylerde alt abdomen manyetik rezonans (MR) görüntüleriyle değerlendirilmesi
Materyal ve Metot: Radyoloji kliniğinde koksidini dışındaki nedenlerle alt abdomen MR incelemesi yapılmış erişkin 216 hastanın görüntüleri retrospektif olarak değerlendirildi. Bu değerlendirmede koksiks (Co) kalınlığı (Co1 orta kesimden), sakrokoksigeal açı, vertebralar arasında füzyon varlığı, koksiksteki vertebra sayısı, sakrokoksigeal eklem açısı, interkoksigeal eklem açısı, koksiks tipi, subluksasyon varlığı, koksiks düz uzunluğu, koksiks eğrisel uzunluğu, sakrum düz uzunluğu, sakrum eğrisel uzunluğu, sakrokoksigeal düz uzunluk, sakrokoksigeal eğrisel uzunluk, sakral açı, koksiks kurvatur indeks, sakrum kurvatur indeks, sakrokoksigeal kurvatur indeks ölçüldü.
Bulgular: Koksiksteki ortalama vertebra sayısı kadınlarda 3,5±0,75, erkeklerde 3,8±0,78 idi. Ortalama koksiks kalınlığı kadınlarda 7,3±1,4 mm erkeklerde 8,4±1,8 mm idi. Vakaların 59 unda (%27,3) subluksasyon izlenirken, 157 (%72,7) sinde subluksasyon saptanmadı. Koksiksin ortalama düz uzunluğu kadınlarda 35,4±6,6 mm, erkeklerde 38,9±8,7 mm olarak ölçüldü. Koksiks eğrisel uzunluğu ise kadınlarda37,5±7,2 mm, erkeklerde 41,7±91 mm idi. Kadın ve erkeklerde en yaygın koksiks tipi 98 (%45,4) kişi ile tip 2 koksiksti. Sakrokoksigeal açı kadınlarda 109±15 derece iken erkeklerde 113±13 derece olarak ölçüldü.
Sonuç: Asemptomatik bireylerdeki koksiks vertebra anatomisinin bilinmesi koksidinideki gereksiz cerrahi girişimleri önleyebilir. Ayrıca koksidinili hastaları da içeren daha geniş kapsamlı çalışmalara ihtiyaç olduğunu düşünüyoruz.

Anahtar Kelimeler: Koksiks anatomisi, Manyetik rezonans görüntüleme, Sakrokoksigeal açı, Koksigeal açı

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Introduction

The coccyx, also known as the tailbone, is considered to be a vestigial remnant of a tail, and is the final segment of the human backbone (1). The word coccyx originates from the name of the cuckoo in Greek, because it resembles the curved beak of the bird (2, 3). In 70-80 % of people , the coccyx consists of 3-5 coccygeal vertebrae and approximately 4 segments (4, 5). The coccyx constitutes only 0.4% of the dry weight of the vertebral column (6). The length of the coccyx varies among individuals but approximately 10% of this difference is related to height. (7) The first coccygeal vertebra is usually the largest and articulates the distal part of the sacrum or becomes fused in some people (8).

Since abnormalities in coccyx morphology may cause pain, it is important to know the natural physiological structure (9). It can be evaluated with plain radiography, which is the oldest technique, computed tomography (CT) or magnetic resonance imaging (MRI). The coccyx is composed of rudimentary intervertebral discs or fusions of small bone segments. Postacchini and Massobrio established a radiological classification of the coccyx on radiographic examination (10), according to which (5), the coccyx is divided into five types; type 1: slight curve, type 2: forward curve, type 3: sharp angle between Co1 and Co2, type 4: anterior subluxation, and type 5: retroverted (10).

The anatomy and morphology of the coccyx varies from person to person. When the person is seated, the coccyx acts as a weight-bearing structure, providing positional support to the anus and the adhesions sites of the pelvic floor tendons (11,12).

Understanding normal adult coccyx morphology and morphometry will provide a better understanding of coccyx-related pathologies. 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.

Methods

A retrospective review was made of the images of 250 adult patients who underwent MR imaging of the lower abdomen for reasons other than coccydynia in the Department of Radiology between July 2018 and December 2018. Approval for the study was granted by the Local Ethics Committee (decision number:07, dated: 05.07.2018).

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. Patients with a history of surgery and pelvic mass were excluded. The study included 216 patients aged 18-78 years, comprising 86 (39.8%) males and 130 (60.2%) females, who were examined for the anatomy of the coccyx through coronal, sagittal and axial planes of MRI examinations. The resulting images were separated into female and male gender groups.

For the MR images, 3 T scanners (Magnetom Skyra, Siemens Healthcare, Erlangen, Germany) were used. The morphometric parameters were evaluated on the sagittal images and morphological evaluation was made on the axial, sagittal and coronal images. The sagittal T2 weighted images were used for the morphometric parameters, which were obtained with TR 3770, TE 99, NEX 1 and a slice thickness of 6 mm. First, the images were transferred to the workstation (Syngo VIA console, Siemens). All of the measurements were made with the aid of these images and were obtained by two experienced radiologists and a physical therapy and rehabilitation specialist.

In this evaluation, measurements were taken of coccyx (Co) thickness (from Co1 middle section), sacrococcygeal angle (the angle between the first sacral vertebra and the first coccygeal vertebra)(Fig.1), fusion between vertebrae (bone continuity between adjacent vertebrae in sagittal slices), number of coccygeal vertebrae, sacrococcygeal joint angle (the angle between the fifth sacral vertebra and the first coccygeal vertebra)(Fig.2), intercoccygeal joint angle (the angle between the first and second coccygeal vertebrae) (Fig.3), coccyx type , presence of subluxation, coccyx flat length (Fig.4), coccyx curvature length (Fig.5), sacrum flat length, sacrum curvature length, sacrococcygeal flat length, sacrococcygeal curvature index, sacral angle (angle between the top contour of the sacrum and the line parallel to the ground) (Fig.6), coccyx curvature index (calculated from straight coccyx length divided by curved coccyx length X100), sacrum curvature index (calculated from sacral straight length divided by curved sacral length X100), and the sacrococcygeal curvature index (calculated from straight sacrococcygeal length divided by curved sacrococcygeal length X100).

The data obtained in the study were analyzed using SSPS 20.0 software. For the evaluation of the data , parametric tests were used for the normally distributed variables, and non-parametric tests were used for the variables that were not normally distributed. The *T*-test
was used for the significance test of the difference between two mean values, and the ANOVA test was used for the comparison of more than two mean values. The Chi-square test was used for the categorical variables. The measurements were compared for both intra-observer and interobserver agreement using Pearson's correlation test. A value of $p<0.05$ was considered statistically significant.

Results

In this study, a total of 216 MRI were evaluated and the measurements were obtained in the sagittal plane. The patients comprised 130 (60.2%) females aged 43.11±12.5 years (range, 18-59 years) and 86 (39.8%) males, aged

46.24±15.7 years (range, 21-78 years). Intra and interobserver variability for the measurements was determined to be <5%.

Fig.1 The measurement of sacrococcygeal angle; the angle between the first sacral vertebra and the first coccygeal vertebra

Fig.2 The measurement of sacrococcygeal joint angle; the angle between the fifth sacral vertebra and the first coccygeal vertebra

The coccyx thickness and the number of vertebrae

A significant difference was determined between males and females in terms of vertebral count(p=0.03) and vertebral thickness(p=0.00).

The mean number of coccyx vertebrae was 3.5 ± 0.75 in females and 3.8 ± 0.78 in males. The mean vertebral count was statistically significantly higher in males than females (p=0.03).

The mean coccyx thickness was 7.3 ±1.4 mm in females and 8.4±1.8 in males and the difference was statistically significant (p=0.00). The mean thickness of the first coccyx vertebra was higher in males than females. A positive correlation was determined between age and coccyx thickness (p=0.00) (r = + 0.261), demonstrating that the thickness of the coccyx increases with age. A positive correlation was determined between coccyx thickness and the number of vertebrae (p=0.003) (r=+0.204).

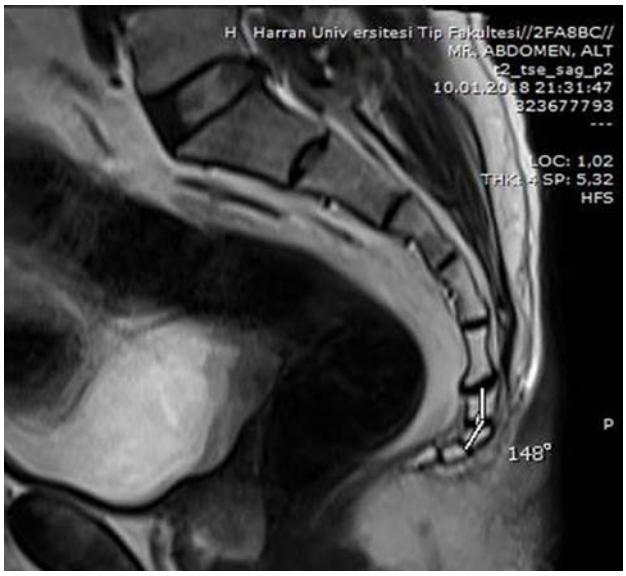

Fig.3 The measurement of intercoccygeal joint angle; the angle between the first and second coccygeal vertebrae

Fig.4 The measurement of coccyx flat length

Joint subluxation and fusion

Fusion was determined in 132 (61.1%) patients (82 females, 50 males) and not in 84(38.9%) patients (48 fe-

males, 36 males). There was a significant relationship between fusion and intercoccygeal joint angle(p=0.037). In patients with fusion, the angle of intercoccygeal joint was greater. The mean intercoccygeal angle was 152.25±16.66 in the fusion-positive patients, and 146.73±21 in those with no fusion. A significant relationship was determined between the number of vertebrae and fusion (p=0.00). The number of vertebrae in individuals with fusion was observed to be higher demonstrating that as the number of vertebrae increased, so the probability of fusion increased.

Fig.5 The measurement of coccyx curvature length

Fig.6 The measurement of sacral angle; angle between the top contour of the sacrum and the line parallel to the ground

Subluxation was determined in 59 (27.3%) cases, and not in 157(72.7%) cases. There were significant differences between subluxation and vertebral count (p=0.028) and sacrococcygeal joint angle (p=0.026). The mean sacrococcygeal joint angle was 170.7±17.3 in the subluxation group and 165.7±13.4 in the non- subluxation group. The mean number of vertebrae was 3.8±0.79 in the subluxation group and 3.6±0.75 in the non-subluxation group.

Coccyx straight length, coccyx curvilinear length, sacrum straight length, sacrum curvilinear length, curvature index

The mean length of the coccyx was 35.4±6.6 mm in females and 38.9±8.7 mm in males. The mean straight length of the sacrum was 108.4±9.7 mm in females and 115.8±8.9 mm in males. The sacrococcygeal straight length was 126.7±12.8 mm in females and 137.8±14.3 mm in males. The mean length of the coccyx curvature was 37.5±7.2 mm in females and 41.7±9.1 mm in males. The curvature length of the sacrum was 116.2±9.2 mm in females and 124.8±11.2 mm in males. There were significant differences between the genders in respect of the coccyx straight length, coccyx curvilinear length, sacrum straight length, sacrum curvilinear length, sacrococcygeal straight length, and sacrococcygeal curvilinear length (p=0.00).

Type of coccyx

The most common coccyx type in both males and females was type II coccyx in 98 (45.4%) patients, followed by type I in 73 (33.8%), type III in 32 (14.8%), and other types (type 4 and 5) in 13 (6%). There were significant differences between sacrococcygeal straight length, coccygeal straight length, vertebral count, sacrococcygeal angle, intercoccygeal joint angle curvature index and coccyx types ($p<0.05$). Coccyx curvilinear length was determined to be statistically significant (p=0.051). No significant difference was found between the coccyx types in respect of age and gender. In terms of vertebrae number, there was a significant difference between type I and the other type group, between types II and III, between type III and type II and the other type group, and between the other type group and type I and type III. The number of vertebrae in type IV and V was significantly more than in type I (p=0.012). The number of vertebrae was significantly higher in type II than in type III (p=0.036). The number of vertebrae was significantly higher in type IV and V than in type III (p=0.005).

Sacrococcygeal angle, sacrococcygeal joint angle, intercoccygeal angle, intercoccygeal joint angle, sacral angle

The sacrococcygeal angle was 109±15 degrees in females and 113±13 in males. The sacrococcygeal angle was statistically different between the types of coccyx (p=0.000). In type I the sacrococcygeal angle was measured as 117

degrees, in type II 108 degrees, type III 101 degrees and the other group 124 degrees.

Discussion

It is normal for there to be differences between individuals in the structure of the coccyx. With recent advances in radiological imaging methods, the number of studies investigating coccyx anatomy and morphology has increased considerably. Knowledge of the normal structure of the coccyx plays an important role in diagnosing coccydynia and other diseases. Therefore, the aim of this study was to determine the normal findings of the coccyx. There are few studies in literature related to the anatomy and morphometry of the normal adult coccyx. To the best of our knowledge this study constitutes the most comprehensive measurement and evaluation.

The results of the study showed that type II coccyx was the most common type, followed by type I. Przybylski et al. (12) also found type II coccyx to be the most common type in a study of a Polish population. However, unlike the current study, the second most common type in the Polish study was type III. Again, in contrast to the current study, Tetiker et al (13) found type I to be the most common in a Turkish population in the western part of the country. This can be attributed to regional differences, as the current study was conducted in the south east of Turkey, where it is customary for people to sit on the ground.

In another study of an Egyptian population, Shalaby et al reported type I coccyx at the rate of 41% and type II at 31% (11). Woon et al. found that 64% of subjects had type I coccyx (1) and Kerimoglu et al. also reported type I as the most common type of coccyx. (5). The reason for the higher frequency of type II coccyx in the current study can be considered to be due to the prevalence of sitting cross-legged on the ground from childhood. Genetic characteristics and lifestyles of humans can also affect the type and morphology of coccyx.

The highest vertebrae count was found to be 4 (54.2%) in the current study patients, which was consistent with findings in literature. In studies by Tetiker et al (13) and Woon et al (10), 4 coccygeal vertebrae were reported most commonly (64%, 76%, respectively), whereas Shalaby et al. found that most subjects had 3 coccygeal vertebrae (63%) (11).

In the current study, a significant difference was determined between males and females in terms of the number and thickness of the vertebrae. In males, the number of vertebrae in the coccyx and the thickness of Co 1 were higher than in females. There was also found to be a positive correlation between age and coccyx thickness. In other words, an increase in coccyx thickness was observed with age. This could be due to the increased load on the coccyx with age and may be a part of the normal growth process. A positive correlation was also determined between the number of vertebrae and thickness. Thus, as the number of vertebrae increased, so the Co1 thickness increased. To the best of our knowledge, there are no studies in literature on this point.

Fusion may be complete or partial and may be sacrococcygeal or intercoccygeal. In the current study, a significant relationship was determined between vertebral fusion and the number of vertebrae. As the number of vertebrae increases in the coccyx, so the probability of fusion increases. A significant relationship was found between vertebral fusion and the angle of intercoccygeal joint as patients with fusion had a larger angle of intercoccygeal joint. Similarly, Tetiker et al. also found a significant relationship between fusion and vertebral count (13).

No relationship was determined between subluxation and gender. However, Shalaby et al. found that subluxation was more common in females (11). A significant difference was determined between the genders in respect of coccyx straight length, coccyx curvilinear length, sacrum straight length, sacrum curvilinear length, sacrococcygeal straight length, and sacrococcygeal curvilinear length. All the values were greater in males than females. These morphometric values were similar to those of Tetiker et al (13). Tetiker reports that 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 also be useful in cases requiring surgical removal of the coccyx.

A limitation of this study was the lack of data such as height, weight, and body mass index, which affect the coccyx morphology and morphometry.

In conclusion, knowledge of the vertebrae anatomy of asymptomatic patients may prevent unnecessary surgery in coccydynia. Wide ranges of similar studies are needed to be done with patients with coccydynia.

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Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee (include name of committee + reference number) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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