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Investigation of the Relationship of the Sacroiliac Joint with the Sacrum in Patients with Ankylosing Spondylitis

Investigación de la Relación de la Articulación Sacroilíaca con el Sacro en Pacientes con Espondilitis Anquilosante

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SUMMARY: Ankylosing spondylitis (AS) is a chronic inflammatory disease that primarily affects the sacroiliac joints and axial skeleton. This study investigated the relationship between sacral morphometry and sacroiliac joint cross-sectional area in patients with AS using magnetic resonance imaging (MRI). A retrospective morphometric analysis was performed on MRI scans from 160 individuals, including 80 patients with AS (40 women and 40 men) and 80 age- and sex-matched healthy controls. Multiple sacral morphometric parameters were measured in the sagittal, axial, and coronal planes, together with the bilateral sacroiliac joint cross-sectional areas. Male patients exhibited significantly greater sacral dimensions than female patients for several morphometric parameters. Compared with controls, both male and female patients with AS demonstrated significantly higher sacral slope values and markedly reduced bilateral sacroiliac joint cross-sectional areas ($p<0.001$). Significant correlations were identified between sacroiliac joint area and several sacral morphometric measurements, including posterior sacral length, sacral area, posterior sacral curvature length, intercornual distance, and sacral slope. These findings indicate that AS is associated with significant alterations in sacral morphology and substantial narrowing of the sacroiliac joint. MRI-based morphometric assessment may provide valuable complementary information for the structural evaluation of patients with AS and contribute to a better understanding of disease-related anatomical changes.

KEY WORDS: Ankylosing spondylitis; Sacrum; Sacroiliac joint; Magnetic resonance imaging; Morphometry.

INTRODUCTION

Ankylosing spondylitis (AS) is a chronic rheumatic disease that predominantly affects the axial skeleton, causing pain and functional impairment (Ertem, 2025). AS is a complex autoimmune disease with a global prevalence of 0.5-0.9%, more common in men than women (Jamshidi *et al*., 2014). AS is an autoinflammatory disease triggered by the innate immune system (Mauro *et al*., 2021). AS causes inflammation in the art. sacroiliaca. This joint is located between the os sacrum and os coxae. It is the largest axial joint of the body and connects the columna vertebralis to the os coxae. It provides load transfer between the vertebrae lumbales and the lower limbs. Its main function is to distribute the load carried by the columna vertebralis to the lower extremities, which it does through the ilium (DSc 2021). Inflammation of the art. sacroiliaca is one of the first signs of AS. Inflammation often spreads to the joints between the vertebrae forming the columna vertebralis (Weber & Baraliakos, 2018). Changes in the art. sacroiliaca at the onset of the disease lead to progressive structural changes, resulting in chronic pain, impaired physical function, and decreased quality of life (Dubash *et al*., 2018). Individuals with AS complain of persistent low back pain and stiffness between the ages of 20-40 (Cohen, 2005). Magnetic Resonance Imaging (MRI) shows both inflammatory and structural changes in the art. sacroiliaca and columna vertebralis, which are essential for early evaluation of AS (Oostveen, 1999;

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Weber & Baraliakos, 2018; Robinson *et al*., 2019). In the majority of AS patients, combined effects of environment and genetics have been observed (Burgos-Vargas *et al*., 1997). First-generation relatives, 8.2% (441/5 390); second-generation relatives, 1.0% (8/834); and third-generation relatives, 0.7% (7/997) have been reported to be predisposed to AS (Brown *et al*., 2000). Clinical findings and radiologic appearances in AS

Inflammatory spinal pain is a pain that starts in the lumbar region and continues with morning stiffness (Calin *et al*., 1977). Especially in the later stages of the disease, individuals mobility decreases and their mobilization is restricted. After a while, this situation turns into a more serious situation as individuals gradually begin to restrict their own movements. Because although many new treatment options have been developed for AS, exercise therapy remains the cornerstone of AS treatment (Ertem, 2025).

In AS, anterior chest wall pain (Wenker & Quint, 2025). Neurologic involvement (Karasick *et al*., 1995). Ophthalmic involvement (Rothova *et al*., 1996). Cardiovascular involvement, gastrointestinal involvement (Bakici*et al*., 2021). Renal involvement (Strobel & Fritschka, 1998). In this study, the measurements of the os sacrum and the correlation of the os sacrum and art. sacroiliaca in patients diagnosed with AS were compared with the control group. It was evaluated whether there was a clinical relationship between them.

MATERIAL AND METHOD

This study was conducted in the Department of Rheumatology, Malatya Training and Research Hospital, Malatya Provincial Health Directorate. Our study was conducted by examining the records of patients who came to the Department of Rheumatology between 2022 and 2024. Ethical approval was obtained from Malatya Turgut Özal University Non-Interventional Clinical Research Ethics Committee (decision dated 09.05.2024 and numbered 2023/ 28-158825). Our study included images of a total of 160 individuals (40 women with ankylosing spondylitis, 40 men with ankylosing spondylitis, 40 healthy women and 40 healthy men) between the ages of 18-72 years, taken with MRI device from patient records admitted to the hospital between 2022-2024. The sample of our study was determined by power analysis method.

Magnetic Resonance Imaging Protocol

For our study, axial T1-weighted and T2-weighted, coronal FLAIR and sagittal T2-weighted images were obtained using an MRI SIEMENS Amira (Enlargen, Germany) 1.5 Tesla device. MRI protocol: 3D T1-MPRAGE; flip angle: 8°; field of view (FOV): 250 mm; number of slices: 192; slice thickness: 1 mm; matrix: 205x320; repetition time: 2200 ms; echo time: 2.79 ms.

Analysis of MR Images and Measurements

T1, T2, Localizer weighted images were saved in Digital Imaging and Communication in Medicine (DICOM) data format and transferred to the computer for structural analysis. The transferred images were loaded one by one into the MicroDICOM program and specific regions were analyzed. MicroDICOM is a program created with the most common image processing software for primary processing and preservation of medical images. It contains the DICOM image, patient information, other labels and displays them together. With the many tools it offers; it is a radiological imaging program that allows measurements such as length, angle, circle, cross-sectional area. Length measurements on MicroDICOM are calculated in mm and area measurements are calculated in mm^2 (Arulmurugan & Anandakumar, 2018). The measurements taken in our study are organized in Figure 1. How the measurements were made is explained below.

Measurements in the sagittal plane

- **Anterior sacral length (ASL):** It is found by measuring the distance between the promontorium of the sacrum and the anterior inferior of the 5th sacral vertebra (Fig. 1A).
- **Posterior sacral length (PSL):** The distance between the posterior superior of the 1st sacral vertebra and the anterior inferior of the sacral vertebra (Fig. 1B).
- **Anterior sacral curvature length (ASEU):** Measurement of the length of curvature from the promontorium of the sacrum to the 5th sacral vertebra (Fig. 1C).
- **Posterior sacral curvature length (PSEL):** Measurement of the length of curvature from the posterior superior of the sacrum to the posterior inferior of the 5th sacral vertebra (Fig. 1D).
- **Sacral area (SA):** Measurement of the area of the vertebrae from the 1st sacral vertebra to the 5th sacral vertebra (Bakici *et al*., 2021) (Fig. 1E)
- **Sacral slope (SS):** Found by measuring the angle between the upper end sacral plate of the 1st sacral vertebra and the line segment drawn parallel to the horizontal (Marty *et al*., 2002) (Fig. 1F).
- **Sacrum base angle (SBA):** It is obtained by measuring the angulation between the line segment drawn along the sacral endplate and the line segment drawn along the posterior wall of the S1 vertebral corpus (Wang *et al*., 2008) (Fig. 1G).

Measurements in the axial plane

- **Sacrum width (SW):** It is obtained by measuring the maximum transverse distance of the compression of the os sacrum in the axial plane (Basaloglu *et al*., 2005) (Fig. 1H).
- **Intercornual distance (ID):** It is obtained by measuring the distance between the horns of the cornu sacrales (Acar, 2018) (Fig. 1I).
- **Antero posterior length of the s1 vertebral corpus (APL):** It is obtained by measuring the linear distance from the anterior to the most posterior point of the S1 vertebral corpus (Fig. 1J) .
- **Maximum transverse length of the s1 vertebral corpus (MTL):** It is the measurement of the linear distance between the two farthest transverse points on the S1 vertebral corpus (Triwidodo *et al*., 2021) (Fig. 1K).

Measurements in the coronal plane

- **Ventral straight length (VDL):** It is obtained by measuring the straight length from the promontorum in the coronal plane along the midline to the anterior edge of the last sacral vertebra (Triwidodo *et al*., 2021). Ventral Flat Width (VFW): It is obtained by measuring the maximum linear ventral distance from the facies pelvica of the os sacrum in the coronal plane (Triwidodo *et al*., 2021) (Fig. 1L).
- **Length of linea transversae (LTL):** The 4 lines that run transversely on the facies pelvica of the sacrum are called linea transversae. On both sides of these lines there are holes called foramina sacralia anterior. The length of the linea transversae is measured by drawing transverse lines through the holes called foramina sacralia anterior (Bakici *et al*., 2021) (Fig. 1M).
- **Art. sacroiliaca cross-sectional area measurement (ASICA):** It is based on the measurement of the entire cross-sectional area of Art. sacroiliaca by means of a dot plot combination (Bang *et al*., 2022) (Fig. 1N).

Biostatistical Data Analysis

Qualitative data from the variables included in the study were summarized with number (percentage). The conformity of quantitative data to normal distribution was evaluated by Kolmogorov Smirnov test. Quantitative data that did not show normal distribution were summarized with median (minimum-maximum), while quantitative data showing normal distribution were summarized with mean±standard deviation. In statistical analyses, categorical variables were compared using Pearson chi-square test. For quantitative variables, independent sample t-test or Mann Whitney U test was used for comparisons between two independent groups based on normal distribution. Sperman Rho correlation coefficient was used to determine whether there was a relationship between variables. A value of $p<0.05$ was considered statistically significant in the statistical analysis. All analyses were performed using IBM SPSS Statistics 26.0 for Windows (New York; USA).

RESULTS

In our study, the mean age of the patient group was 42.21±12.29 years, while the mean age of the control group was 38.74±13.44 years and there was no statistically significant difference between the two groups (p=0.090). In terms of sex distribution, the proportions of females and males were equal in both groups (50.0%, n=40 females and 50.0%, n=40 males) and no significant difference was observed between the groups in terms of sex (p=1.0).

In terms of age variable, the median age of women was 41.5 years (min=18, max=69), while the median age of men was 40 years (min=19, max=72). There was no statistically significant difference between sexes in terms of age variable (p=0.504) (Table I).

Table I. Comparison of demographic characteristics of patient and control groups.

Variables	Groups		p
	Patient	Control	
Age (Years)	42.21±12.29	38.74±13.44	0.090*
Sex			
Female	40 (50.0)	40 (50.0)	1.0**
Male	40 (50.0)	40 (50.0)	

*: Independent samples t-test; **: Pearson chi-square test

Morphometric comparison between sexes in the control group revealed significant differences in sacral morphology. In the sagittal plane, males had significantly greater anterior and posterior sacral lengths, sacral area, and anterior and posterior sacral curvature lengths (all $p < 0.001$), whereas the sacral base angle was significantly greater in females ($p = 0.049$). In the axial plane, males exhibited a greater maximum transverse length of the S1 vertebral body ($p = 0.010$) as well as significantly higher transverse line 1, line 2, and line 3 measurements (all $p \leq 0.002$). In the coronal plane, both left and right sacroiliac joint cross-sectional areas were significantly larger in males (left: $p = 0.008$; right: $p = 0.003$). No significant sex-related differences were observed for the remaining parameters. These findings indicate significant sexual dimorphism in sacral morphology within the control group (Table II).

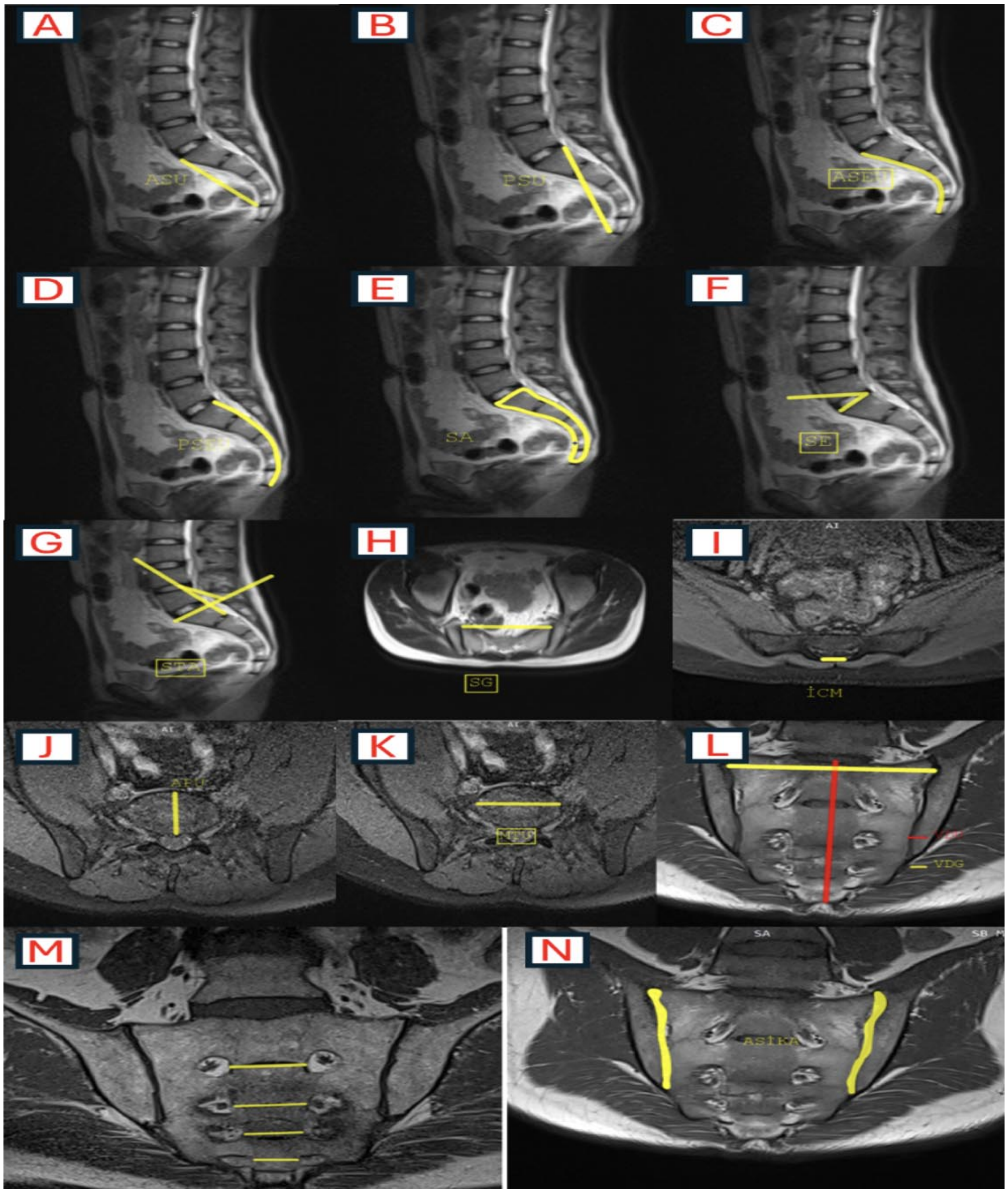

Fig. 1. Measurements Taken in Our Study. It is found by measuring the distance between the promontorium of the sacrum and the anterior inferior of the 5th sacral vertebra (ASL): (Fig. 1A). The distance between the posterior superior of the 1st sacral vertebra and the anterior inferior of the sacral vertebra (PSL): (Fig. 1B). Measurement of the length of curvature from the promontorium of the sacrum to the 5th sacral vertebra (ASCL): (Fig. 1C). Measurement of the length of curvature from the posterior superior of the sacrum to the posterior inferior of the 5th sacral vertebra (PSCL): (Fig. 1D). Measurement of the area of the vertebrae from the 1st sacral vertebra to the 5th sacral vertebra (SA): (Fig. 1E). Found by measuring the angle between the upper end sacral plate of the 1st sacral vertebra and the line segment drawn parallel to the horizontal (SE): (Fig. 1F). It is obtained by measuring the angulation between the line segment drawn along the sacral endplate and the line segment drawn along the posterior wall of the S1 vertebral corpus (SBA): (Fig. 1G). It is obtained by measuring the maximum transverse distance of the compression of the os sacrum in the axial plane (SW): (Fig 1H). It is obtained by measuring the distance between the horns of the cornu sacrales (ID). (Fig. I). It is obtained by measuring the linear distance from the anterior to the most posterior point of the S1 vertebral corpus (APL): (Fig 1J). It is the measurement of the linear distance between the two farthest transverse points on the S1 vertebral corpus (MTL): (Fig. 1K). It is obtained by measuring the straight length from the promontorum in the coronal plane along the midline to the anterior edge of the last sacral vertebra (VDL). It is obtained by measuring the maximum linear ventral distance from the facies pelvica of the os sacrum in the coronal plane (VFW): (Fig. 1L). The 4 lines that run transversely on the facies pelvica of the sacrum are called linea transversae. On both sides of these lines there are holes called foramina sacralia anterior. The length of the linea transversae is measured by drawing transverse lines through the holes called foramina sacralia anterior (LTL): (Fig. 1M). It is based on the measurement of the entire cross-sectional area of Art. sacroiliaca by means of a dot plot combination (ASICA): (Fig. 1N).

Table II. Comparison of Os sacrum morphometric measurements by sex in the control group.

	Variables	Sex		p
		Male	Female	
Saggital	Anterior Sacral Length (mm)	107.7±8.4	100.02±5.68	**<0.001***
	Posterior Sacral Length (mm)	108±8.32	99.47±5.61	**<0.001***
	Sacral Area (mm_)	1351.02(1111.09-1575.11)	1238.33(1110.27-1475.92)	**<0.001****
	Anterior Sacral Curvature Length (mm)	117.08±9.32	107.65±7.11	**<0.001***
	Posterior Sacral Curvature Length (mm)	118.19(90.16-137.42)	106.31(96.02-124.9)	**<0.001****
	Sacral base angle (°)	91±0.76	91.37±0.91	**0.049***
	Sacral Slope (°)	40.02(31.91-53.75)	39.69(25.69-46.21)	0.341**
Axial	Maximum Transverse Length of S1 Vertebral Corpus (mm)	48.38(42.39-62.78)	46.66(38.03-54.61)	**0.010****
	Anteroposterior Length of S1 Vertebral Corpus (mm)	33.15(24.89-43.13)	31.63(25.73-43.77)	0.066**
	Sacrum Width (mm)	99.05±5.05	97.65±5.12	0.224*
	Intercornual Distance (mm)	9.91±1.14	9.63±1.09	0.263*
Coronal	Ventral Straight Length (mm)	111.46(97.18-129.81)	110.03(88.71-123.04)	0.218**
	Ventral Flat Width (mm)	115.83(101.8-129.46)	114.52(82.33-124.08)	0.066**
	Transverse Line 1 (mm)	29.57(27.18-33.44)	28.6(24.55-30.94)	**<0.001****
	Transverse Line 2 (mm)	27.71±1.18	26.8±1	**<0.001***
	Transverse Line 3 (mm)	25.44±1.09	24.7±1.02	**0.002***
	Transverse Line 4 (mm)	21.64(17.85-23.64)	21.93(17.46-23.25)	0.577**
	Sacroiliac Joint Cross-Sectional Area Left (mm^2)	107.13(101.8-118.26)	103.76(99.39-124.87)	**0.008****
	Sacroiliac Joint Cross-Sectional Area right (mm^2)	107.17(102.23-115.86)	103.78(100.06-126.67)	**0.003****

Variables are given as mean ± standard deviation or median (minimum–maximum) according to the normality of the distribution.; *: Independent sample t-test; **: Mann Whitney U test

In the morphometric comparison between sexes in the patient group, in males; anterior sacral length (106.02–8.65 vs. 100.23–6.75, p=0.001), posterior sacral length (105.08–8.84 vs. 98.73–6.27, p<0.001), sacral area (1325.61 vs. 1219.01, p<0.001), anterior sacral curvature length (113.52–10.61 vs. 106.41–7.85, p=0.001) and posterior sacral curvature length (111.77–9.94 *vs.* 104.44–8.18, p<0.001) were significantly higher. The maximum transverse length (49.57–4.32 vs. 47.60–4.00, p=0.037) and anteroposterior length (33.92–3.49 *vs.* 31.72–3.17, p=0.004) of the S1 vertebral corpus in the axial plane was measured more in men. Linea transversa 1 (29.02–1.16 vs. 28.35–0.97, p=0.006), linea transversa 2 (27.06–1.05 vs. 26.52–1.12, p=0.029) and linea transversa 3 (25.06–1.06 vs. 24.42–1.25, p=0.016) were significantly higher in men. No significant difference was found between the sexes in sacrum base angle, sacral slope, sacrum width, intercornual distance, ventral straight length and width, linea transversa 4 and art. sacroiliaca cross-sectional areas (Table III)

Table III. Comparison of Os sacrum morphometric measurements according to sex in the patient group.

	Variables	Sex		p
		Male	Female	
Saggital	Anterior Sacral Length (mm)	106.02±8.65	100.23±6.75	**0.001***
	Posterior Sacral Length (mm)	105.08±8.84	98.73±6.27	**<0.001***
	Sacral Area(mm^2)	1325.61(1089.54-2696.86)	1219.01(1026.42-1492.56)	**<0.001****
	Anterior Sacral Curvature Length (mm)	113.52±10.61	106.41±7.85	**0.001***
	Posterior Sacral Curvature Length (mm)	111.77±9.94	104.44±8.18	**<0.001***
	Sacral base angle (°)	91.4(86.49-94.78)	91.15(86.25-94.83)	0.197**
	Sacral Slope (°)	43.41(30.84-49.98)	42.3(26.46-48.9)	0.329**
Axial	Maximum Transverse Length of S1 Vertebral Corpus (mm)	49.57±4.32	47.60±4.00	**0.037***
	Anteroposterior Length of S1 Vertebral Corpus (mm)	33.92±3.49	31.72±3.17	**0.004***
	Sacrum Width (mm)	97.29±5.76	98.08±5.79	0.542*
	Intercornual Distance (mm)	9.66(8.1-13.06)	9.23(7.29-11.89)	0.093**
Coronal	Ventral Straight Length (mm)	109±10.51	110.57±7.96	0.455*
	Ventral Flat Width (mm)	113.13±6.05	114.35±6.48	0.385*
	Transverse Line 1 (mm)	29.02±1.16	28.35±0.97	**0.006***
	Transverse Line 2 (mm)	27.06±1.05	26.52±1.12	**0.029***
	Transverse Line 3 (mm)	25.06±1.06	24.42±1.25	**0.016***
	Transverse Line 4 (mm)	21.95(17.87-25.45)	21.92(17.5-23.87)	0.444**
	Sacroiliac Joint Cross-Sectional Area Left (mm^2)	60.73±9.02	58.95±9.46	0.390*
	Sacroiliac Joint Cross-Sectional Area right (mm^2)	60.28±9.04	59.1±9.37	0.570*

Variables are given as mean ± standard deviation or median (minimum–maximum) according to the normality of the distribution.; *: Independent sample t-test; **: Mann Whitney U test

In the morphometric comparison between the male patient and male control groups, the posterior sacral curvature length in the sagittal plane was significantly higher in the control group (118.19 *vs.* 112.89, p=0.024). Sacral slope value was significantly higher in the patient group (143.41 *vs.* 140.02, p=0.030). Ventral flat width in the coronal plane was higher in the control group (116.01±6.52 *vs.* 113.13±6.05, p=0.044). Linea transversa 1 and 2 measurements were also significantly higher in the control group (p=0.011 and p=0.011, respectively). Left and right art. sacroiliaca cross-sectional areas were significantly larger in the control group than in the patient group (left: 107.27±3.47 *vs.* 60.73±9.02, p<0.001; right: 107.35±3.37 *vs.* 60.28±9.04, p<0.001). There was no statistically significant difference between the groups in other parameters. These findings indicate that there are significant differences in os sacrum morphology between the male patient and control groups (Table IV).

Table IV. Comparison of Os sacrum morphometric measurements in male patient and male control groups.

	Variables	Group		p
		Patient	**Control**	
Saggital	Anterior Sacral Length (mm)	106.02±8.65	107.7±8.4	0.381*
	Posterior Sacral Length (mm)	105.08±8.84	108±8.32	0.132*
	Sacral Area (mm²)	1325.61(1089.54-2696.86)	1351.02(1111.09-1575.11)	0.482**
	Anterior Sacral Curvature Length (mm)	113.52±10.61	117.08±9.32	0.115*
	Posterior Sacral Curvature Length (mm)	112.89(92.26-129.13)	118.19(90.16-137.42)	**0.024****
	Sacral base angle (°)	91.4(86.49-94.78)	91.12(89.03-92.38)	0.081**
	Sacral Slope (°)	43.41(30.84-49.98)	40.02(31.91-53.75)	**0.030****
Axial	Maximum Transverse Length of S1 Vertebral Corpus (mm)	49.88(38.19-60.51)	48.38(42.39-62.78)	0.082**
	Anteroposterior Length of S1 Vertebral Corpus (mm)	33.92±3.49	33.43±3.59	0.537*
	Sacrum Width (mm)	97.29±5.76	99.05±5.05	0.152*
	Intercornual Distance (mm)	9.66(8.1-13.06)	9.83(6.7-11.89)	0.331**
Coronal	Ventral Straight Length (mm)	109±10.51	111.95±7.79	0.158*
	Ventral Flat Width (mm)	113.13±6.05	116.01±6.52	**0.044***
	Transverse Line 1 (mm)	29.02±1.16	29.77±1.4	**0.011***
	Transverse Line 2 (mm)	27.06±1.05	27.71±1.18	**0.011***
	Transverse Line 3 (mm)	25.06±1.06	25.44±1.09	0.125*
	Transverse Line 4 (mm)	21.91±1.35	21.61±1.18	0.285*
	Sacroiliac Joint Cross-Sectional Area Left (mm²)	60.73±9.02	107.27±3.47	**<0.001***
	Sacroiliac Joint Cross-Sectional Area right (mm²)	60.28±9.04	107.35±3.37	**<0.001***

Variables are given as mean ± standard deviation or median (minimum–maximum) according to the normality of the distribution.; *: Independent sample t-test; **: Mann Whitney U test

Table V. Comparison of Os sacrum morphometric measurements in female patient and female control groups.

	Variables	Group		p
		Patient	**Control**	
Saggital	Anterior Sacral Length (mm)	100.23±6.75	100.02±5.68	0.883*
	Posterior Sacral Length (mm)	98.73±6.27	99.47±5.61	0.580*
	Sacral Area (mm²)	1219.01(1026.42-1492.56)	1238.33(1110.27-1475.92)	0.825**
	Anterior Sacral Curvature Length (mm)	106.41±7.85	107.65±7.11	0.462*
	Posterior Sacral Curvature Length (mm)	104.44±8.18	106.84±7.45	0.174**
	Sacral base angle (°)	91.15(86.25-94.83)	91.47(88.87-93.16)	0.244**
	Sacral Slope (°)	42.3(26.46-48.9)	39.69(25.69-46.21)	**0.004****
Axial	Maximum Transverse Length of S1 Vertebral Corpus (mm)	47.6±4	46.21±4	0.124*
	Anteroposterior Length of S1 Vertebral Corpus (mm)	32.32(24.5-37.39)	31.63(25.73-43.77)	0.751**
	Sacrum Width (mm)	98.08±5.79	97.65±5.12	0.727*
	Intercornual Distance (mm)	9.3±1.15	9.63±1.09	0.181*
Coronal	Ventral Straight Length (mm)	109.81(93.71-126.87)	110.03(88.71-123.04)	0.570**
	Ventral Flat Width (mm)	114.44(95.1-128.03)	114.52(82.33-124.08)	0.439**
	Transverse Line 1 (mm)	28.38(26.16-30.26)	28.6(24.55-30.94)	0.213**
	Transverse Line 2 (mm)	26.52±1.12	26.8±1	0.238*
	Transverse Line 3 (mm)	24.42±1.25	24.7±1.02	0.284*
	Transverse Line 4 (mm)	21.92(17.5-23.87)	21.93(17.46-23.25)	0.758**
	Sacroiliac Joint Cross-Sectional Area Left (mm²)	60.4(37.58-79.96)	103.76(99.39-124.87)	**<0.001****
	Sacroiliac Joint Cross-Sectional Area right (mm²)	60.28(36.28-75.37)	103.78(100.06-126.67)	**<0.001****

Variables are given as mean ± standard deviation or median (minimum–maximum) according to the normality of the distribution.; *: Independent sample t-test; **: Mann Whitney U test

Table VI. Correlation of Os sacrum morphometric measurements with Art. sacroiliac Cross-Sectional areas by groups.

			All Patient (n=160)		Male Patient/Control (n=80)		Female Patient/Control (n=80)		Male Patient/ Female Patient (n=80)		Male Control/ Female Control (n=80)	
			Sacroiliac Joint Cross-Sectional Area Left (mm²)	Sacroiliac Joint Cross-Sectional Area right (mm²)	Sacroiliac Joint Cross-Sectional Area Left (mm²)	Sacroiliac Joint Cross-Sectional Area right (mm²)	Sacroiliac Joint Cross-Sectional Area Left (mm²)	Sacroiliac Joint Cross-Sectional Area right (mm²)	Sacroiliac Joint Cross-Sectional Area Left (mm²)	Sacroiliac Joint Cross-Sectional Area right (mm²)	Sacroiliac Joint Cross-Sectional Area Left (mm²)	Sacroiliac Joint Cross-Sectional Area right (mm²)
Saggital	Anterior Sacral Length (mm)	r	0.147	0.146	0.148	0.149	0.105	0.098	0.344	0.295	0.134	0.170
		p	0.063	0.066	0.190	0.188	0.356	0.390	**0.002**	**0.008**	0.238	0.131
	Posterior Sacral Length (mm)	r	0.218	0.216	0.192	0.191	0.207	0.200	0.385	0.339	0.131	0.166
		p	**0.006**	**0.006**	0.087	0.090	0.065	0.075	**<0.001**	**0.002**	0.246	0.142
	Sacral Area(mm²)	r	0.207	0.195	0.128	0.125	0.267	0.245	0.395	0.351	0.330	0.327
		p	**0.009**	**0.013**	0.237	0.269	**0.016**	**0.028**	**<0.001**	**0.001**	**0.003**	**0.003**
	Anterior Sacral Curvature Length (mm)	r	0.195	0.195	0.166	0.167	0.166	0.152	0.313	0.255	0.059	0.115
		p	**0.014**	**0.013**	0.141	0.139	0.142	0.178	**0.005**	**0.023**	0.602	0.311
	Posterior Sacral Curvature Length (mm)	r	0.250	0.243	0.232	0.229	0.241	0.213	0.329	0.246	0.063	0.111
		p	**0.001**	**0.002**	**0.039**	**0.041**	**0.031**	0.057	**0.003**	**0.028**	0.582	0.328
	Sacral base angle (°)	r	0.010	-0.026	-0.150	-0.155	0.198	0.131	0.133	0.019	0.008	-0.016
		p	0.897	0.745	0.186	0.169	0.078	0.245	0.240	0.869	0.947	0.888
	Sacral Slope (°)	r	-0.239	-0.227	-0.154	-0.149	-0.329	-0.314	-0.029	-0.017	0.066	0.103
		p	**0.002**	**0.004**	0.172	0.188	**0.003**	**0.005**	0.798	0.880	0.562	0.364
Axial	Maximum Transverse Length of S1 Vertebral Corpus (mm)	r	-0.125	-0.132	-0.163	-0.175	-0.142	-0.152	0.224	0.238	-0.113	-0.153
		p	0.115	0.096	0.148	0.122	0.208	0.178	**0.046**	**0.034**	0.317	0.176
	Anteroposterior Length of S1 Vertebral Corpus (mm)	r	-0.031	-0.024	-0.097	-0.095	-0.005	0.012	0.164	0.227	-0.189	-0.228
		p	0.701	0.763	0.394	0.404	0.968	0.915	0.146	**0.043**	0.093	**0.042**
	Sacrum Width (mm)	r	0.116	0.140	0.146	0.166	0.065	0.088	0.127	0.205	0.106	0.129
		p	0.146	0.078	0.196	0.142	0.567	0.439	0.263	0.069	0.350	0.255
	Intercornual Distance (mm)	r	0.228	0.225	0.099	0.110	0.309	0.302	0.251	0.300	0.233	0.167
		p	**0.004**	**0.004**	0.381	0.331	**0.005**	**0.006**	**0.025**	**0.007**	**0.037**	0.140
Coronal	Ventral Straight Length (mm)	r	0.097	0.100	0.160	0.147	0.025	0.045	0.114	0.100	0.159	0.182
		p	0.224	0.210	0.156	0.192	0.825	0.693	0.315	0.379	0.160	0.106
	Ventral Flat Width (mm)	r	0.069	0.068	0.131	0.134	-0.019	-0.035	-0.019	-0.013	0.078	0.065
		p	0.386	0.394	0.248	0.236	0.870	0.761	0.867	0.911	0.493	0.569
	Transverse Line 1 (mm)	r	0.148	0.153	0.147	0.149	0.096	0.098	0.053	0.060	-0.003	0.011
		p	0.061	0.054	0.194	0.186	0.395	0.386	0.643	0.598	0.978	0.925
	Transverse Line 2 (mm)	r	0.224	0.213	0.202	0.203	0.197	0.160	0.188	0.178	0.058	0.036
		p	**0.004**	**0.007**	0.073	0.071	0.079	0.156	0.095	0.113	0.610	0.750
	Transverse Line 3 (mm)	r	0.146	0.126	0.115	0.113	0.134	0.092	0.129	0.108	0.051	-0.010
		p	0.065	0.113	0.308	0.317	0.236	0.418	0.256	0.338	0.653	0.930
	Transverse Line 4 (mm)	r	0.054	0.036	-0.019	-0.024	0.123	0.085	0.370	0.375	-0.088	-0.173
		p	0.496	0.655	0.867	0.836	0.276	0.454	**0.001**	**0.001**	0.435	0.126

*p<0.05,**p<0.01; r: Spearman's rho correlation coefficient.

In the morphometric comparison between female patient and female control groups, the sacral slope value in the sagittal plane in Table V was found to be significantly higher in the patient group (142.3 *vs.* 139.69, p=0.004). Left and right art. sacroiliaca cross-sectional areas were significantly larger in the control group than in the patient group (left: 103.76 *vs.* 60.4, p<0.001; right: 103.78 *vs.* 60.28, p<0.001). There was no statistically significant difference between the groups in all other parameters examined (anterior sacral length, posterior sacral length, sacral area, anterior and posterior sacral curvature lengths, sacrum base angle, S1 vertebral corpus measurements, sacrum width, intercornual distance, ventral straight length and width, linea transversa measurements (Table V). These findings suggest that there are limited differences in os sacrum morphology between the female patient and control groups.

In the whole patient group; posterior sacral length (r=0.218, p=0.006), sacral area (r=0.207, p=0.009), anterior sacral curvature length (r=0.195, p=0.014), posterior sacral curvature length (r=0.250, p=0.001), intercornual distance (r=0.228, p=0.004) and linea transversa 2 (r=0.224, p=0.004) were significantly positively correlated with left art. sacroiliaca cross-sectional area. A significant negative correlation was found with sacral slope (r=-0.239, p=0.002). In the male patient/control group, there was a positive correlation between posterior sacral curvature length and both left (r=0.232, p=0.039) and right (r=0.229, p=0.041) art. sacroiliaca cross-sectional area. In the female patient/ control group; sacral area was positively correlated with both left (r=0.267, p=0.016) and right (r=0.245, p=0.028) art. sacroiliaca cross-sectional area, posterior sacral curvature length (r=0.241, p=0.031) was positively correlated with left art. sacroiliaca cross-sectional area, sacral slope was positively correlated with both left (r=-0.329, p=0.003) and right (r=-0.314, p=0.005) arth. sacroiliaca cross-sectional area, and intercornual distance was positively correlated with both left (r=0.309, p=0.005) and right (r=0.302, p=0.006) arth. sacroiliaca cross-sectional area. In the male patient/female patient group, sacral area (r=0.267, p=0.016), posterior sacral curvature length (r=0.241, p=0.031), and intercornual distance (r=0.309, p=0.005) were positively correlated with left art. sacroiliaca cross-sectional area and negatively correlated with sacral slope (r=-0.329, p=0.003). In the comparison of male and female control; anterior sacral length (r=0.344, p=0.002), posterior sacral length (r=0.385, p<0.001), sacral area (r=0.395, p<0.001), anterior and posterior sacral curvature lengths (r=0.313, p=0.005; r=0.329, p=0.003), maximum transverse length of S1 vertebral corpus (r=0.224, p=0.046), intercornual distance (r=0.251, p=0.025) and linea transversa 4 (r=0.370, p=0.001) and left art. sacroiliaca cross-sectional area. Table VI.

DISCUSSION

Studies investigating the relationship of the art. sacroiliaca with the sacrum in AS patients are limited. In our study, MR images were used for bone measurement instead of CT images because they are preferred for the diagnosis of AS. In previous studies, the relationship of art. sacroiliaca to the sacrum was mostly evaluated in terms of sex and it was examined whether there was a difference. In these studies, anterior and posterior sacral length, anterior and posterior sacral curvature length, and sacral area measurement parameters were found to be higher in males than females (Gaya-Sancho, 2018; Torimitsu *et al*., 2018; Bakici *et al*., 2021). Similar findings were found in our study. In previous studies, no significant difference was found between sexes in sacral curvature angle measurement in healthy individuals (Sudhir *et al*., 2016) (Table I). Aksoy *et al*. (2024). compared the sacral inclination angle in AS patients with and without syndesmophytes and found a higher angle in patients with syndesmophytes. In our study, no significant difference was observed between male and female groups in healthy subjects. When male and female patient groups with AS were compared with the control group, it was observed that the sacral inclination angle was statistically higher in both male and female patient groups. The sacrum base angle was found to be statistically higher in women in our study, while there was no significant difference between sexes in Erbek's study (Erbek, 2004). In the literature, there are studies reporting that the maximum transverse length of the S1 vertebral corpus is longer in men (Torimitsu *et al*., 2018; Etli *et al*., 2019). Bas¸alog˘lu *et al*. (2005) reported that there was no significant difference. While there are studies reporting that the antero-posterior length of the S1 vertebral corpus is longer in males (Torimitsu *et al*., 2018; Zhan *et al*., 2018; Etli *et al*., 2019) there are also studies reporting that it is not related to sex (Acar, 2018; Mishra, 2024). Erbek (2004) found that the intercornual distance was greater in males, while Acar (2018) reported that there was no significant difference between men and women. In our study, there was a statistically significant increase in the maximum transverse length of the S1 vertebral corpus, while no significant difference was found in the antero-posterior length of the S1 vertebral corpus, sacrum width and intercornual distance measurements. In our study, no statistically significant difference was observed when the mid ventral straight length was compared in terms of sex. There are studies reporting that the mid ventral straight length measurement is higher in males (94, 114, 115). Basaloglu *et al*. (2005) reported that mid ventral flat width was higher in males, and Triwidodo *et al*. (2021) found that it was higher in females. In our study, there was no significant difference between sexs in mid ventral flat width. There are studies that found similar results to our study (Mazumdar & Ray, 2012). When linea trasversa lengths were examined in our study, it was observed that linea trasversa 1, linea trasversa 2 and linea trasversa 3 measurements were longer in males, while linea trasversa 4 did not change significantly. Bakici *et al*. (2021) reported that all of the linea trasversa lengths, Triwidodo *et al*. (2021) reported that linea trasversa 1, Bang *et al*. (2022) compared the cross-sectional area of the art. sacroiliaca between the patient group with AS and the control group with X-ray images and found that the cross-sectional area of the art. sacroiliaca was higher in the control group. Sex comparison was not made in this study. In our study, the right and left art. sacroiliaca cross-sectional area in healthy individuals was found to be higher in men.

When male and female patient groups with AS were compared with the control group, it was observed that the cross-sectional areas of the right and left art. sacroiliaca were statistically lower in both male and female patient groups. When male and female patient groups with AS were compared with each other, no significant difference was detected in the cross-sectional areas of the right and left art. sacroiliaca.

CONCLUSIONS

In AS, which causes inflammation and various anomalies in the columna vertebralis and art. sacroiliaca, measurements of the os sacrum and cross-sectional area of the art. sacroiliaca are very important. We obtained significant results with significant differences in some parameters of the os sacrum and the cross-sectional area of the art. sacroiliaca. Studies on measuring the relationship of the art. sacroiliaca with the os sacrum in individuals with AS are limited. In both male and female patients with AS; the sacral inclination angle was measured higher than in the control group. Since there is no study in the literature comparing the cross-sectional area of the art. sacroiliaca and os sacrum morphometric examination in AS patients compared to the control group, we believe that we will shed light on the literature and a larger sample set should be studied.

Limitations. The disadvantages of our study include the fact that more participants were not studied, that is, our sample was limited, and more comprehensively, we do not know when the patients were diagnosed with AS, lack of disease history, and the fact that we could not use CT images, which are more effective for bone measurement, since MR images are preferred for the diagnosis of AS.

Ethical approval

Ethical approval was obtained from the Non-Invasive Clinical Trials Ethics Committee of Malatya Turgut Özal University (decision dated 09.05.2024 and numbered 2023/28-158825).

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ÜZÜMCÜOGLU, R.; PEKMEZ, H.; UZUN, G.B.; BALIKCIIÇIÇEK, I.; KAYA, Z. & ARPACI, M. F. Investigación de la relación de la articulación sacroilíaca con el sacro en pacientes con espondilitis anquilosante. *Int. J. Morphol., 44(3)*:984-993, 2026.

RESUMEN: La espondilitis anquilosante (EA) es una enfermedad inflamatoria crónica que afecta principalmente a las articulaciones sacroilíacas y al esqueleto axial. Este estudio investigó la relación entre la morfometría del sacro y el área transversal de la articulación sacroilíaca en pacientes con EA mediante resonancia magnética (RM). Se realizó un análisis morfométrico retrospectivo de imágenes de RM de 160 individuos, incluyendo 80 pacientes con EA (40 mujeres y 40 hombres) y 80 controles sanos pareados por edad y sexo. Se evaluaron múltiples parámetros morfométricos del sacro en los planos sagital, axial y coronal, junto con el área transversal bilateral de la articulación sacroilíaca. Los hombres con EA presentaron dimensiones sacras significativamente mayores que las mujeres en varios parámetros morfométricos. En comparación con los controles, tanto hombres como mujeres con EA mostraron una inclinación sacra significativamente mayor y una reducción marcada del área transversal de ambas articulaciones sacroilíacas (p<0,001). Además, se observaron correlaciones significativas entre el área de la articulación sacroilíaca y diversos parámetros morfométricos del sacro, incluyendo la longitud sacra posterior, el área sacra, la longitud de la curvatura sacra posterior, la distancia intercornual y la inclinación sacra. Estos hallazgos indican que la EA se asocia con alteraciones significativas en la morfología del sacro y con un estrechamiento importante de la articulación sacroilíaca. La evaluación morfométrica mediante resonancia magnética puede aportar información complementaria útil para la valoración estructural de pacientes con EA y contribuir a una mejor comprensión de los cambios anatómicos relacionados con la enfermedad.

PALABRAS CLAVE: Espondilitis anquilosante; Sacro; Articulación sacroilíaca; Resonancia magnética; Morfometría.

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