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Comparison Of Three Methods for Calculation of Sacroiliac Joint Index in Different Age Groups in Bone Scintigraphy

Kemik Sintigrafisinde Farklı Yaş Gruplarında Sakroiliak Eklem İndeksinin Hesaplanmasında Kullanılan Üç Yöntemin Karşılaştırılması

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Abstract

Objective: The aim of this study is to evaluate three techniques for calculating the sacroiliac joint (SIJ) index by bone scintigraphy in patients.

Materials and Methods: Patients (n:160) who did not exhibit abnormalities on bone scan were analyzed and were divided into 4 groups; 3-20 years, 21-40 years, 41-60 years, and 61-86 years, respectively. Irregular and rectangular regions of interest (ROI) were used for the first and second methods, respectively. Horizontal rectangular ROI was selected for the last technique. The SIJ index was calculated by the following formula: SIJ count/sacrum count.

Results: There was no difference between the averages of all three methods according to the right and left SIJ index ($p>0.05$). The averages of all SIJ values differed for the three methods ($p<0.05$). The average of the first method's values for all three situations was lower than the averages of the other two methods' values ($p<0.05$). The first technique had a lower mean for the right SIJ index value than the other two techniques ($p<0.05$). The average of females was lower than males for all SIJ index values. The lowest average was detected at the age of 61 and above for three methods for both genders. All methods differed according to age ($p<0.05$). A relationship was detected between the age and all three index values of all techniques.

Conclusion: A threshold value for each method should be identified using a fixed reference point for each age group taking into account gender.

Keywords: Sacroiliac joint index, Bone scintigraphy, Sacroiliitis, Region of interest, Tc-99m MDP.

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Öz

Amaç: Bu çalışmanın amacı hastalarda kemik sintigrafisi ile sakroiliak eklem (SİE) indeksinin hesaplanmasına yönelik üç tekniğin değerlendirilmesidir.

Gereç ve Yöntemler: Kemik sintigrafisinde anormallik izlenmeyen hastalar (n:160) analiz edildi ve 4 gruba ayrıldı; sırasıyla 3-20 yaş, 21-40 yaş, 41-60 yaş, 61-86 yaş. Birinci ve ikinci yöntem için sırasıyla düzensiz ve dikdörtgen ilgi alanı (ROI) kullanıldı. Son yöntem için yatay dikdörtgen ROI seçildi. SİE indeksi şu formülle hesaplandı: SİE sayımı/sakrum sayımı.

Bulgular: Üç yöntemde sağ ve sol SiE indeksi ortalamaları arasında fark yoktu ($p>0,05$). Tüm SİE değerlerinin ortalamaları üç yöntem için farklılık gösterdi ($p<0,05$). Her üç durum için de birinci yöntemin değerlerinin ortalaması diğer iki yöntemin değerlerinin ortalamasından düşüktü ($p<0,05$). Sağ SİE indeks değeri için ilk metodun ortalaması diğer iki yönteme göre daha düşüktü ($p<0.05$). Kadınların ortalaması tüm SİE indeks değerleri için erkeklerden daha düşüktü. Her iki cinsiyette de üç yöntem için en düşük ortalama 61 yaş ve üzerinde tespit edildi. Tüm yöntemler yaşa göre farklılık gösterdi ($p<0,05$). Bütün metodlarda yaş ile her üç indeks değeri arasında korelasyon tespit edildi.

Sonuç: Her yöntem için cinsiyet dikkate alınarak her yaş grubu için sabit bir referans noktası kullanılarak bir eşik değeri belirlenmelidir.

Anahtar Kelimeler: Sakroiliak eklem indeksi, Kemik sintigrafisi, Sakroileit, İlgi alanı, Tc-99m MDP.

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Introduction

The Sacroiliac joint (SIJ) provides a connection of the right ilium, sacrum, and left ilium. This joint also ensures body weight is transferred to the lower extremities. This joint's anatomy has a wide spectrum in adults (1). SIJ structure varies according to age, gender, and race. SIJ is more flexible in women to facilitate a baby's transition during birth. Therefore, women are more susceptible to stress on the structures surrounding the joint. On the other hand, SIJ is stronger in men, and as a result of that more load is added to the joint (1-4).

Sacroiliitis is an inflammatory disease and it causes SIJ dysfunction and pain. Patients generally complain of lumbar pain and ~ 70% of individuals are affected throughout their lifetime. While sports injuries and trauma cause pain in young patients, joint degeneration causes in an elderly population (1-4).

It can be difficult to differentiate SIJ pain from various diseases that cause similar symptoms. Patients with SIJ pain usually consult physicians with deep-rooted thigh pain that radiates to the lower extremities. The pain can be unilateral or bilateral and might increase with sitting down, long walking, or walking uphill. Therefore, detailed medical history is very important for diagnosis. Various tests are used to reveal SIJ pain during physical examination (1-3).

Dysfunction of this joint affects the life quality of individuals. Therefore, correct diagnosis is important. Imaging modalities play a vital role in sacroiliitis diagnosis. Various imaging methods have been used to demonstrate anatomical changes in sacroiliitis. Direct radiography is generally a preferred method by clinicians due to its easy accessibility. Furthermore, it is also a safe method and utilized with several advantages such as low radiation dose and low cost (4-5).

Computed Tomography (CT) provides detailed information about the SIJ anatomy, soft tissue surrounding the joint, and adjacent structures compared to radiography. It can show erosion, sclerosis, and narrowing of joint space (3-4).

Magnetic Resonance Imaging (MRI) demonstrates the early and inflammatory stage of sacroiliitis due to its high resolution. Therefore, it is accepted as the gold standard for the diagnosis of sacroiliitis. Furthermore, MRI usually detects bone marrow edema which is a key finding in active disease. It can visualize erosion, and changes in SIJ and soft tissues (4-7).

Nuclear medicine imaging methods can also be helpful for the evaluation of early sacroiliitis. Technetium (Tc)-99m labeled methylene diphosphonate (MDP) bone scintigraphy is the most commonly used nuclear medicine scan for sacroiliitis. Bone scintigraphy can detect early inflammatory and metabolic changes earlier than plain radiography (4,8,9). This method can also show the width of inflammation. Whole-body imaging is performed with a bone scan. Therefore, it provides valuable information about affected other joints in patients, especially with arthritis. However, this method is not specific and does not provide detailed anatomical information. It is combined with an X-ray or MRI.

Scintigraphic images are evaluated visually. The area where the radioactive substance accumulates pathologically is regarded as positive. SIJ value that is obtained by the ratio of SIJ counts to sacrum count as a quantitative parameter increases its specificity (10). If the SIJ count is greater than the sacrum count, it has clinical significance for the diagnosis of sacroiliitis.

Various studies that compare different regions of interest (ROI) methods in different age groups for the determination of the normal values of the SIJ index were reported in the literature (11-12).

From this point of view, we aimed to investigate the variability of normal values of the SIJ index according to different ROI methods. Therefore, we separated the cases into 4 groups based on these studies. It is known that Tc-99m MDP is physiologically distributed in the SIJ. It was reported that the normal SIJ value of each population is different. Based on this information, we also aimed to investigate the factors affecting the SIJ value in individuals whose bone scintigraphy was reported as normal in our society. Therefore, we analyzed whether this index varies according to age, gender, and laterality.

Materials and Methods

Patients who underwent bone scintigraphy from May 2015 to June 2016 at Kahramanmaras Sutcu Imam University, Faculty of Medicine, Department of Nuclear Medicine were analyzed. Local Ethics Committee approval was obtained with decision number 16 dated 29.06.2016.

Patients with a history of inflammatory arthritis, low back pain, orthopedic surgery, and multiple osteoblastic bone metastasis were excluded from the study.

One hundred sixty patients were included in this cross-sectional research. Patients who did not have pathological findings on bone scintigraphies were included in this study to assess normal values of the SIJ index as a control.

Scintigraphic imaging was carried out 3 hours after intravenous administration of 740 MBq Tc-99m MDP for adults. The pediatric dosage was calculated according to the guidelines. Imaging was performed with a dual-headed gamma camera (GE Healthcare Discovery NM630) equipped with a low-energy general-purpose collimator. Whole body bone scintigraphy (128x512 matrix) and static images (256x256 matrix) were performed for computer analysis.

Posterior pelvic images were used for analysis. Three different ROI methods were selected based on a literature search.

Irregular-shaped ROI was chosen for the first method. In this method, manual drawings were made around both SIJ and sacrum, separately (Figure 1). The average counts obtained from these drawings were recorded.

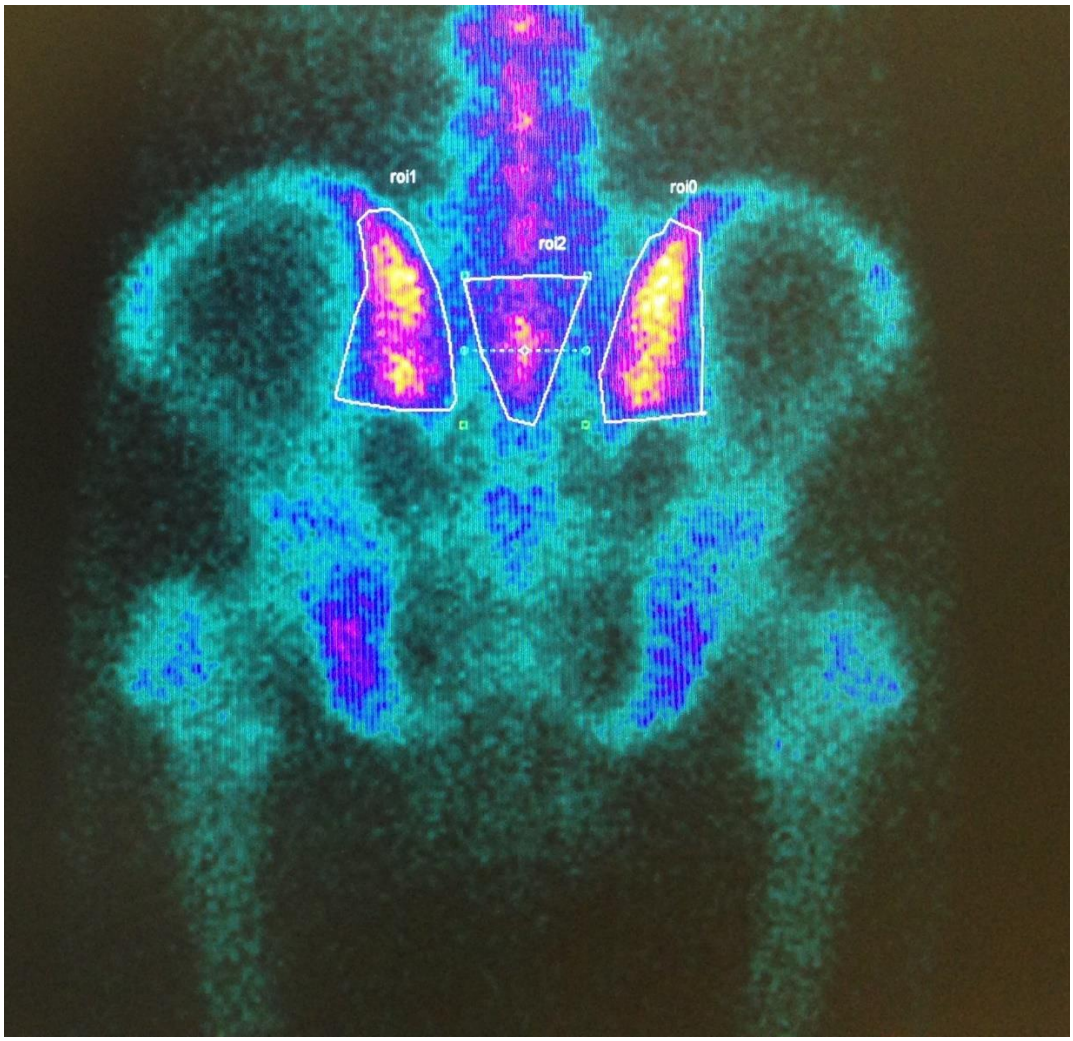


Figure 1. Irregular ROI method. Three ROIs are seen on both sacroiliac joints and sacrum were manually drawn in posterior pelvis image of bone scintigraphy.

Rectangular-shaped ROI was chosen for the second technique and it was automatically placed on the right SIJ, sacrum, and left SIJ, separately (Figure 2). The average counts obtained from these bones were recorded.

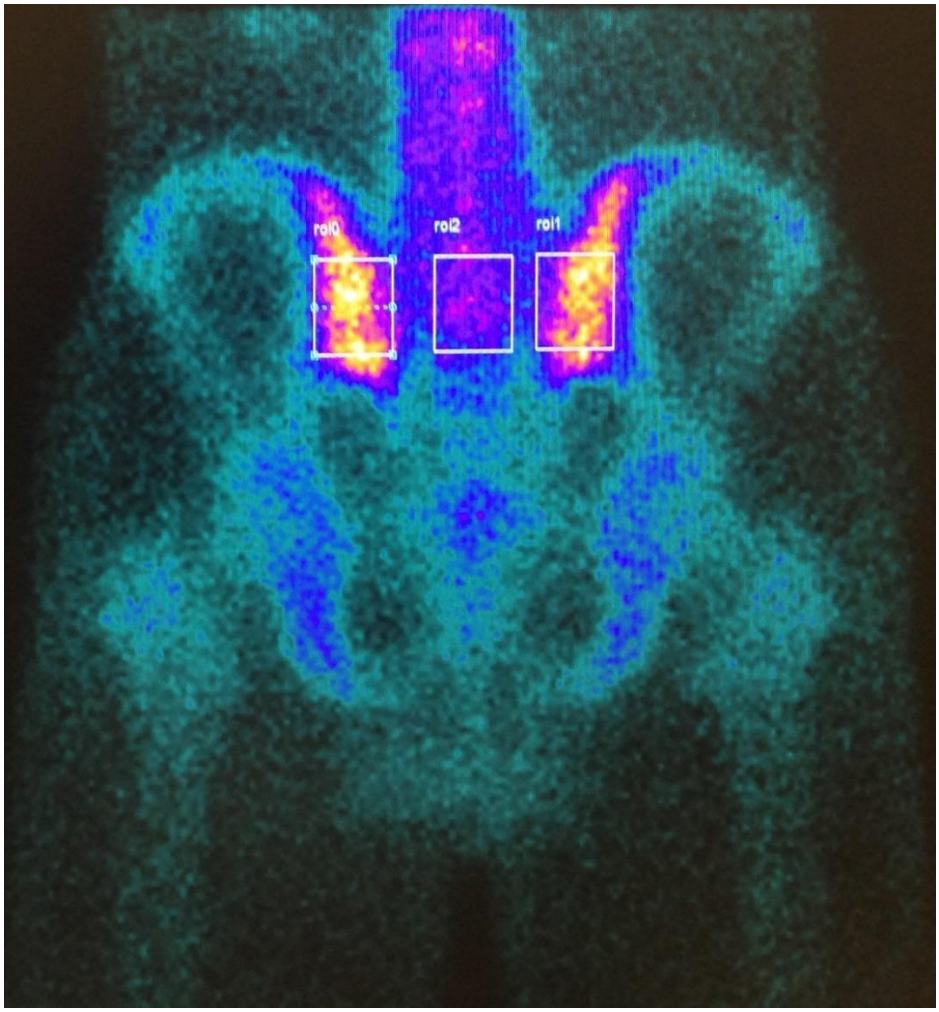


Figure 2. Rectangular ROI method. Same shaped rectangular ROI were placed on both sacroiliac joints and sacrum in posterior pelvis image of bone scintigraphy.

In the third method, a horizontal rectangular ROI was selected. This ROI was automatically placed on the same bone structures. A graph that shows profile peak counts of these bones was obtained and recorded (Figure 3).

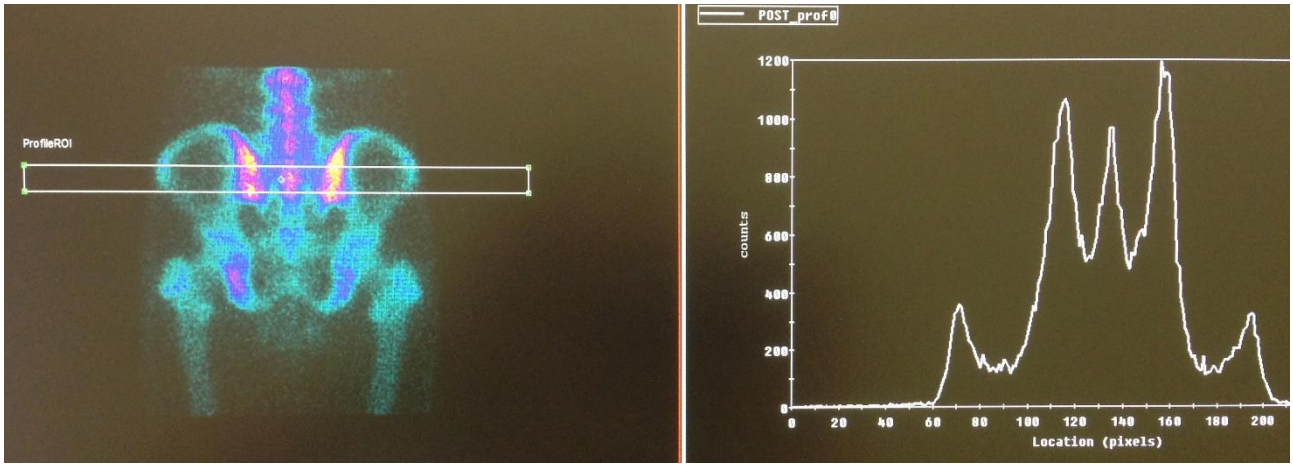


Figure 3. Horizontal rectangular ROI method. A horizontal rectangular ROI was placed on both sacroiliac joints and sacrum in posterior pelvis image of bone scintigraphy. Three separate peaks that shows maximum counts on the profile for both sacroiliac joints and sacrum.

The SIJ index was calculated by the following formula: SIJ count/sacrum count in all three methods.

Statistical Analysis

Statistical Package for the Social Sciences software (IBM SPSS Statistics for Windows, Version 25.0 IBM Corp., Chicago, IL, USA) was used for data analysis. Outlier analysis was performed to check the normality of the data and were excluded from the evaluation. To determine whether the data was suitable for normal distribution, it was first assessed with Kolmogorov-Smirnov/Shapiro-Wilk tests. Normality tests were also supported by skewness-kurtosis and a Q-Q plot graph. Descriptive data were expressed as number (n), percentage (%), and mean±SD (standard deviation) values. In cases where the normality assumption was met, paired sample t-test and if not met Mann Whitney U test, one of the non-parametric tests, were performed for two groups. One-way analysis of variance (ANOVA, F) test was performed to compare the means in more than two groups. Correlation analysis was performed to analyze the relationship between individual variables. Pearson correlation analysis was performed for normally distributed groups. A value of $p < 0.05$ was considered significant statistically.

Results

74 (46,2%) patients were females and 86 (53.8%) patients were males. The average age of the patients differed between females and males ($p<0.05$). The average age of males (90,54) was higher than that of females (68.83). The mean age of cases was found to be 51,85±18 years.

According to studies in the literature, patients were separated into 4 groups with an interval of 20 years. There were 12 patients in the first group (aged 3 to 20 years), 29 patients in the second group (aged 21 to 40 years), 54 patients in the third group (aged 41 to 60 years), and 65 patients in the fourth group (aged 61 to 86 years).

The averages of the three techniques were not different according to the right and left SIJ index as shown in Table 1 ($p>0.05$).

Table 1.

Evaluation of the averages of irregular-shaped ROI, rectangular-shaped ROI, horizonral rectangular ROI methods according to right SIJ index and left SIJ index

Variables	Groups	n	mean±SD	p value
Irregular-shaped ROI	Right SIJ index	160	1,03±0,11	0,681
	Left SIJ index	160	1,03±0,10	
Rectangular-shaped ROI	Right SIJ index	160	1,12±0,12	0,996
	Left SIJ index	160	1,12±0,11	
Horizontal rectangular ROI	Right SIJ index	160	1,13±0,16	0,169
	Left SIJ index	160	1,14±0,17	

ROI: Region of interest, SIJ: Sacroiliac joint

The averages of the right, left, and mean SIJ index values of the patients differed for the three techniques ($p<0.05$). The average of the first method values for all three situations was found to be statistically significantly lower than the average of the other two techniques' values ($p <0.05$) (Table 2).

Table 2.
Comparison of average of irregular-shaped ROI, rectangular-shaped ROI, horizonral rectangular ROI methods according to right, left and mean SIJ values

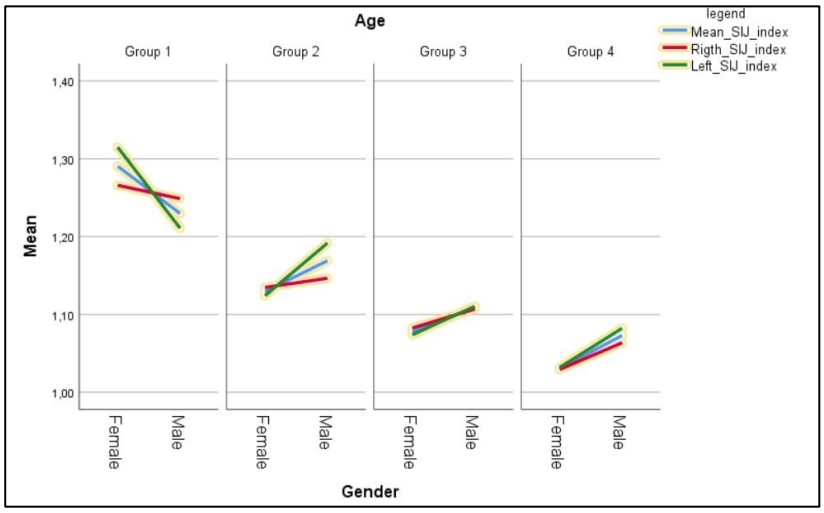
Variables	Groups	n	mean±SD	F	p value
Right SIJ index	Irregular-shaped ROI	160	1,03±0,10	28,893	**0,000***
	Rectangular-shaped ROI	160	1,12±0,11		
	Horizontal rectangular ROI	160	1,13±0,16		
Left SIJ index	Irregular-shaped ROI	160	1,03±0,10	29,672	**0,000***
	Rectangular-shaped ROI	160	1,12±0,11		
	Horizontal rectangular ROI	160	1,14±0,17		
Mean SIJ index	Irregular-shaped ROI	160	1,03±0,09	31,415	**0,000***
	Rectangular-shaped ROI	160	1,12±0,11		
	Horizontal rectangular ROI	160	1,13±0,16		

F test; *p<0.05; ROI: Region of interest, SIJ: Sacroiliac joint.

The mean of three techniques and right, left, and mean SIJ index values were analyzed. The first method had a significantly lower mean for the right SIJ index value than the other two methods (p<0.05).

All SIJ index values were analyzed according to gender. The average of females was lower than males for all three SIJ index values. While the average of females was 1.09±0.14 for the right SIJ index, 1.08±0.14 for the left SIJ index, 1.08±0.13 for the mean SIJ index, the average of males was 1.10±0.13, 1.11±0.13, 1.10±0.13, respectively.

All SIJ index values according to gender were evaluated based on age (Graph 1). The lowest average was detected at the age of 61 and above for all three methods for females and males.



Graph 1. Graphical presentation of right SIJ index, left SIJ index and mean SIJ index values according to gender, based on age.

It was determined that all methods differed according to age as shown in Table 3 (p <0.05). The average of the first group was higher than the third and fourth groups, and the average of the second group was higher than the fourth group for the first and second methods. The average of the first group was higher than the second, third, and fourth groups, and the average of the second group was higher than the fourth group for the third method (p<0.05).

Table 3.

Evaluation of the averages of the irregular-shaped ROI, rectangular-shaped ROI, horizonral rectangular ROI methods according to age

Methods	Age-Groups	n	mean±SD	F	p value
Irregular-shaped ROI	Group 1	12	1,13±0,11	7,662	**0,000***
	Group 2	29	1,06±0,10		
	Group 3	54	1,02±0,09		
	Group 4	65	1,00±0,08		
Rectangular-shaped ROI	Group 1	12	1,23±0,12	8,773	**0,000***
	Group 2	29	1,17±0,11		
	Group 3	54	1,11±0,10		
	Group 4	65	1,09±0,09		
Horizontal rectangular ROI	Group 1	12	1,34±0,13	11,816	**0,000***
	Group 2	29	1,18±0,16		
	Group 3	54	1,12±0,15		
	Group 4	65	1,08±0,13		

ANOVA (F test); *p<0.05; ROI: Region of interest, SIJ: Sacroiliac joint.

A negative medium-level relationship was detected between the patient's age and the first method's right SIJ index value (p<0.05). A negative low-level relationship was detected between the patient's age and the first method left SIJ index value (p<0.05).

A negative medium-level relationship was detected between the patient's age and the second method's right SIJ index value (p<0.05). A negative medium-level relationship was found between the patient's age and the second method left SIJ index value (p<0.05).

A negative medium-level relationship was detected between the age of the patient and the third method's right SIJ index value (p<0.05). A negative medium-level relationship was detected between the patient's age and the third method left SIJ index value (p<0.05).

There was a difference between the averages of all three techniques for the 0-20 age group (p<0.05). The difference was found between the first and third techniques (p<0.05).

There was a difference between the averages of all three techniques for the 21-40 age group (p<0.05). The difference was found between the first and third techniques; the first and second techniques (p<0.05).

There was a difference between the averages of all three techniques for the 41-60 age group ($p<0.05$). There was a difference between the first and third techniques; the first and second techniques ($p<0.05$).

There was a difference between the averages of all three techniques for the age group of 61 years and above ($p<0.05$). There was a difference between the first and third techniques; the first and second techniques ($p<0.05$) (Table 4).

Table 4.

Evaluation of the averages of irregular-shaped ROI, rectangular-shaped ROI, horizonral rectangular ROI methods based on four age groups.

Age groups	Group	n	mean±SD	F	p value
0-20 age group	Irregular-shaped ROI	12	1,13±0,11	8,531	**0,001***
	Rectangular-shaped ROI	12	1,23±0,12		
	Horizontal rectangular ROI	12	1,34±0,14		
21-40 age group	Irregular-shaped ROI	29	1,06±0,10	7,353	**0,001***
	Rectangular-shaped ROI	29	1,17±0,11		
	Horizontal rectangular ROI	29	1,18±0,17		
41-60 age group	Irregular-shaped ROI	54	1,02±0,09	10,999	**0,000***
	Rectangular-shaped ROI	54	1,11±0,10		
	Horizontal rectangular ROI	54	1,12±0,15		
≥ 61 age group	Irregular-shaped ROI	69	1,01±0,08	12,991	**0,000***
	Rectangular-shaped ROI	69	1,10±0,10		
	Horizontal rectangular ROI	69	1,07±0,14		

F test; *$p<0.05$; ROI: Region of interest

Discussion

Quantitative sacroiliac bone scans have been used for a long time (13).

In this study, a total of 160 patients with normal bone scintigraphy were retrospectively evaluated. Three ROI methods were used to calculate quantitative SIJ index in four different age groups.

When the averages of the three methods were evaluated according to laterality in this study, no significant difference was found ($p>0.05$) (Table 1).

The results of this study showed that right, left, and mean SIJ index values of the three methods were different ($p<0.05$) (Table 2). The mean value of the rectangular-shaped ROI method was lower than other methods in our study. In the first method, unlike the second and third methods, all counts from the bone structure are obtained. Additionally, the choice of count type and the distribution of radioactivity in the bone may have caused this result. Furthermore, the second and third methods were more practical than the first method.

All SIJ index values were analyzed according to gender in this study. The results showed that females had lower SIJ index values than males. It may be caused by anatomical and physiological differences in the female and male pelvis. The male pelvis is adapted for weight bearing. Therefore, the male pelvis is narrower and the joint surface is wider. Unlike the male pelvis, the female pelvis is wider to facilitate birth (1-4). This can also be explained by the hormonal status of females.

This study showed that the age group ≥ 61 had the lowest SIJ values in both genders (Graph 1). The mean SIJ value in females was 1.02±0.11 for the right side, and 1.02±0.12 for the left side. The mean SIJ value in male was found 1.06±0.10 and 1.08±0.11 for right and left side, respectively. Radioactive agent uptake is related to blood flow and osteoblastic activity. Bone metabolism decreases with increased age. This result is correlated with this physiological process.

In this study, we found that three ROI drawing techniques in four groups were significantly different from each other (Table 3). The influence of ROI selection is important due to the variability of radiopharmaceutical distribution in the areas we used as a reference.

A negative significant association between age and right/left SIJ index values was found using all three methods in this study ($p<0.05$). This result shows that age affects the SIJ index. Osteoblast activity decreases with aging, thus bone density decreases. At the same time, the SIJ cartilage becomes weaker and degenerative changes can occur in the joint. We believe that the physiological aging process may cause this result.

The average value range of the SIJ index of the three methods was determined as follows: 1.13-1.34 for the first group, 1.06-1.18 for the second group, 1.02-1.12 for the third group, 1.01–1.10 for the fourth group in this study (Table 4). ROI drawing methods may cause different results in different age groups. Differences in bone density, cartilage structure and ligaments of the SIJ as well as SIJ stability in children and adults can also lead to this result.

There are different results on this subject in the literature. In a research study, four different techniques were compared to calculate the SIJ index in a healthy group (n=100). Tiwari et al. reported that there was no difference between these methods in the SIJ index (11). Therefore, the authors underlined that the selection of ROI did not have importance in calculating this index. Elderly patients had the lowest SIJ values (11).

The same authors also stated that SIJ values were changed between 1.06 and 1.36 (11). Additionally, in another study, authors documented that normal SIJ values ranged between 0.9 and 1.14 in eighty-two cases (13). Normal SIJ values can change in every population.

Reyhan et al. reported that right SIJ was lower than left in both genders in 197 patients without any disease (12). SIJ value decreased with increasing age. The authors also stated that body mass index (BMI) and number of births affected the SIJ value. SIJ was decreased with increasing BMI in women.

SIJ value was higher in females in the first method using the sacrum as a background in research that was performed in pediatric patients (n=79). However, no difference was found in the second method using the L5 vertebra as background. Moreover, SIJ values were lower in the second method in this study (15).

Rectangular ROI was used to calculate the SIJ index in a study conducted on 335 people. The lowest value was obtained in the group aged 5 and under (16).

Min. et al. retrospectively evaluated bone scans in patients (n=53) and the SIJ to sacrum ratio was found helpful (17).

Yoon et al. evaluated the diagnostic performance of quantitative single photon emission computed tomography (SPECT)/CT for identifying sacroiliitis. SPECT/CT had 87.5% sensitivity and 56.5% specificity. SIJ/sacrum ratio can be helpful for patients in whom MRI is contraindicated (18).

There was a medium correlation between SPECT/CT and MRI in a study that was performed in 53 patients. The authors concluded that this method might have a role in the diagnosis of active sacroiliitis (19).

In addition to conventional imaging methods, studies related to deep learning have been reported in the literature. Lee et al. developed and evaluated an artificial intelligence (AI) model using MRI images to show sacroiliitis in 296 patients. The authors reported that this model might be used for other clinical conditions (20).

An AI model was developed using pelvic radiographs from patients by Li et al. (21). This model was found to be helpful for diagnosis and management of sacroiliitis.

Bordner et al. developed a deep-learning model using MRI images of patients to show active sacroiliitis. The authors concluded that the diagnostic performance of this AI model was high for the detection of BME (22).

Limitations of this study were a low number of patients and a number of births, body mass index which might affect SIJ values could not evaluated.

Conclusion

Despite advances in imaging technologies, bone scintigraphy still maintains its importance in clinical practice. This method has been used for various clinical indications including detection of sacroiliitis. Bone scintigraphy is an easy-accessible, low cost and sensitive method. SIJ index is a quantitative parameter that increases, the bone scan's specificity. Due to SIJ's complex anatomy and the physiological distribution of the radiopharmaceutical, various factors might affect SIJ index values in individuals. Depending on the ROI selection, the normal SIJ index value varies in the same age group. For this reason, each society should know its own SIJ values considering other factors.

Ethics Committee Approval: The study was approved by the Sutcu Imam University Local Ethics Committee (date:29.06.2016 and decision number:16).

Informed Consent: Written consent was obtained from the participants.

Conflict of Interest: Authors declared no conflict of interest.

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Author Contributions: Idea/Concept: E.S.; Design: E.S.; Supervision: E.S.; Funding: E.S.; Materials: E.S.; Data Collection/Processing: E.S.; Analysis/Interpretation: E.S.; Literature Review: E.S.; Drafting/Writing: E.S.; Critical Review: E.S. The authors have accepted responsibility for the entire content of this manuscript and approved its submission.

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