

# Association Between Acromiohumeral Interval and Isolated Supraspinatus Muscle Tears Using Magnetic Resonance Imaging

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## ABSTRACT

**Objective:** The authors aimed to investigate the acromiohumeral interval (AHI) using Ellman's classification in patients with isolated supraspinatus tendon tears. The AHI differences between patients and controls, in addition to controls, partial tears, or total supraspinatus ruptures, were compared concerning AHI differences.

**Methods:** The imaging was performed using a 1.5 Tesla (T) magnetic resonance imaging (MRI) device and a shoulder coil. The AHI measurements were determined by taking the average of measurements in 3 different planes. For Ellman's classification, the grading of the tear was graded based on how much the depth of the tear or the thickness of the tendon was affected.

**Results:** A total of 304 shoulder MRIs meeting the criteria were included in our study. The study included 41.4% (126/304) without rotator cuff pathology, 30.9% (94/304) with grade 1 tear in the isolated supraspinatus tendon, 6.6% (20/304) individuals with grade 2 tear, 11.8% (36/304) with isolated supraspinatus tendon grade 3 tear, and 9.2% (28/304) with grade 4 tear in the isolated supraspinatus tendon. The AHI values in men were found to be statistically significantly higher than in women. The patient group and the control group showed a significant difference regarding the AHI values. The AHI measurements were significantly lower for the patients with total rupture.

**Conclusion:** The AHI values in isolated supraspinatus tendon injuries, including all tear groups, were found to be significantly lower than those in the patients without rupture; however, there was also a significant difference between total and partial-tear groups.

**Keywords:** Acromion, humerus, MRI, rotator cuff, supraspinatus, tendon injuries

## INTRODUCTION

The rotator cuff muscles must be intact for normal glenohumeral kinetics and shoulder function. A tear in the rotator cuff muscles impairs glenohumeral kinetics, which leads to proximal migration of the humerus and causes glenohumeral arthropathy. The supraspinatus initiates the abduction of the shoulder. The deltoid muscle continues the abduction of the shoulder, which starts on the supraspinatus side, up to 90 degrees. The function of the rotator cuff muscles is to compress the humeral head to the glenoid, increase the contact surface with the glenohumeral joint, and center the humeral head to the glenoid. A tear in the rotator muscles leads to humeral displacement proximally during the abduction movement of the deltoid muscle.<sup>1-4</sup>

The acromiohumeral interval (AHI) has been proposed as a reliable measure for the upward migration of the humeral head. Golding found normal AHI values between 7 and 13 mm using radiography in 150 healthy individuals without rotator cuff injury.<sup>5,6</sup> Weiner and Macnab suggested that the leading cause of proximal migration of the humeral head is that there is no other muscle to prevent the deltoid muscle from pulling up the humeral head due to a supraspinatus tear. Weiner and Macnab's AHI measures 7-14 mm in healthy individuals without rotator cuff damage, while those with 5 mm or less AHI accepted it as a rotator cuff tear.<sup>1,2,5-7</sup>

Hamada et al. proposed a classification system to understand the relationship between rotator cuff arthropathy (RCA) severity and rotator cuff tears. They measured

rotator muscle tears using acromiohumeral interval (AHI) radiography in surgically confirmed patients. They said that the long head of the biceps muscle tried to prevent the proximal migration of the humeral head against the function of the deltoid muscle in patients with rotator muscle tear, and the proximal migration of the humeral head was severe in cases with a tear of the long head of the biceps muscle.<sup>1,2,5,7</sup>

In previous studies, cadavers have measured AHI using direct radiography, ultrasound, and a limited number of magnetic resonance imaging (MRI) studies.<sup>2,8-10</sup> We performed our study with a 1.5 T MRI since MRI has a reasonable contrast resolution in the evaluation of the tendon tear. Since there is insufficient information on this subject and the rotator cuff muscles move dynamically, we compared the patients with isolated supraspinatus tendon tears and ordinary individuals concerning AHI. We also used classification for the severity of the supraspinatus tears and measured AHI in each group. To our knowledge, this study contains one of the largest population groups to present AHI differences for isolated supraspinatus tendon tears.

## MATERIAL AND METHODS

### Study Population

Our institutional review board approved this retrospective study by the ethics committee (Erzincan Binali Yildirim University Ethics Committee of Clinical Research Number: E-26447783-050.06.04-213515 Date: 02.11.2022). Between June 1, 2022, and December 31, 2022, all of the patients who were undergone shoulder MRI were included in the investigation. The study included individuals over 18 years of age with an isolated supraspinatus tear and those over 18 years of age with normal shoulder MRI examinations. Totally 534 patients were screened for this investigation in this period. Those under 18 years of age, low-quality MRIs due to motion artifacts, patients with tumors and other lesions which might

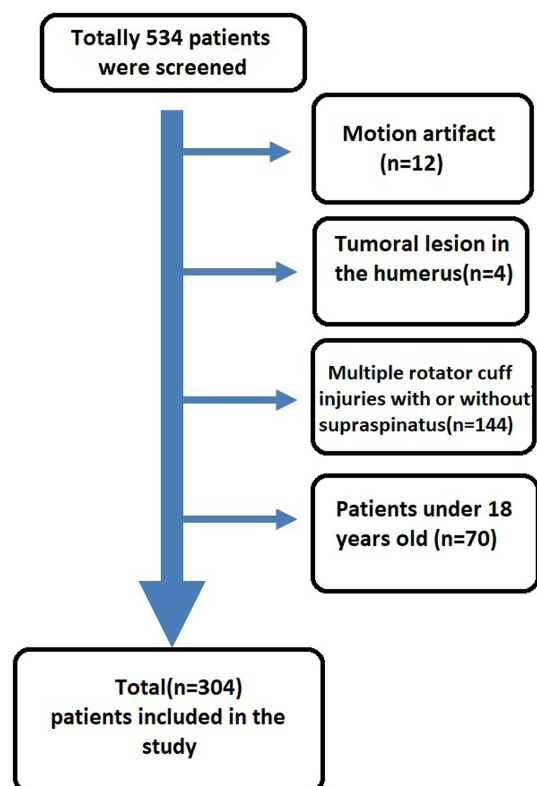
affect the AHI measurement, and patients with combined rotator cuff injuries (rotator cuff tears observed in more than 1 tendon) were excluded from the study. Twelve patients with motion artifacts, 4 patients with tumoral lesions located in the humerus, 144 patients because of more than 1 rotator cuff pathology, including supraspinatus muscle, and 70 patients under 18 years of age were excluded. Finally, 304 patients (188 women and 116 men) were included in the study. One hundred twenty-six individuals constituted the control group without rotator cuff pathology, and the patient group consisted of 178 patients with isolated supraspinatus tendon tears (Figure 1).

### Magnetic Resonance Imaging Protocol

Magnetic resonance imaging was performed with a 1.5 T MRI (Magnetom Aera, Siemens, Erlangen, Germany) device using a (16 channel) shoulder coil. Patients were given a standard position to obtain shoulder MRI, lying on his back and the arm in slight external rotation. T1 coronal, fat-suppressed sagittal proton density (PD), fat-suppressed coronal PD, and axial PD images were obtained for shoulder imaging. T1 weighted turbo spin echoes coronal plane images [Field of view (FOV): 160 mm, slice thickness (ST): 3 mm, time of repetition (TR): 424 ms, time of echo (TE): 11 ms, voxel size: 0.5 × 0.5 × 3 mm]; fat suppressed PD turbo spin echo images (FOV:

### MAIN POINTS

- No significant relationship was found between age and acromiohumeral interval (AHI) in the study.
- In this study, the Ellman degree of tear in the supraspinatus tendon increases as the decrease in AHI becomes evident.
- It can be predicted that it may be associated with the possibility of total rupture in AHI and in cases with severe narrowing.
- Magnetic resonance imaging examination is more useful in the evaluation of AHI and the evaluation of muscle signal intensity and integrity.



**Figure 1.** Diagram showing the study population.

160 mm, ST: 20 mm, TR: 2690 ms, TE: 35 ms, voxel size:  $0.3 \times 0.3 \times 3$  mm).

### Image Analysis and Measurement of the Acromiohumeral Interval

A picture archiving and communication system (Akgün PACS Viewer v7.5, Akgün Software, Ankara, Türkiye) was used to analyze shoulder MRI images in standard digital imaging and medicine (DICOM) formats. Shoulder MRI scans were scanned from the institutional hospital's PACS system archives. Two radiologists performed the measurements with 4 years and 17 years of experience. In order to increase reliability, the measurements were repeated 3 times, and the average value was considered.

The AHI was measured as the shortest interval extending from the acromion's lower cortical border to the humeral head's upper cortical border in T1 weighted coronal plane images (Figure 2).

To classify the tendon tears, the rotator cuff tendons' integrity was evaluated with fat-suppressed PD-weighted images in the sagittal and coronal planes. The degree of partial tears was determined according to Ellman's classification.<sup>11-15</sup> The affected side was not classified as bursal, articular, or intratendinous parts of the tendon. A total tear was defined as a total separation and discontinuity of the tendon or tears of 100% thickness.<sup>7</sup> Patients in the group with isolated supraspinatus tendon tears were classified as follows: grade 1, low-grade partial thickness tears (<3

mm deep or <25% thickness); grade 2, moderate partial thickness tears (3-6 mm deep or approximately 50% of the thickness of the tendon); grade 3, partial tears of the bursal or articular surface with a high-grade partial thickness tear (>6mm deep or more than half of the thickness of the tendon); grade 4, complete or full thickness (100% thickness) tear (Figure 3).<sup>7,11,13-15</sup>

The relationship between AHI and age and gender was evaluated either in this study. The relationship between AHI in normal individuals and patients with the isolated partial or total tear of the supraspinatus tendon was investigated. The correlation between the degree of tear and AHI values was also studied with statistical calculations

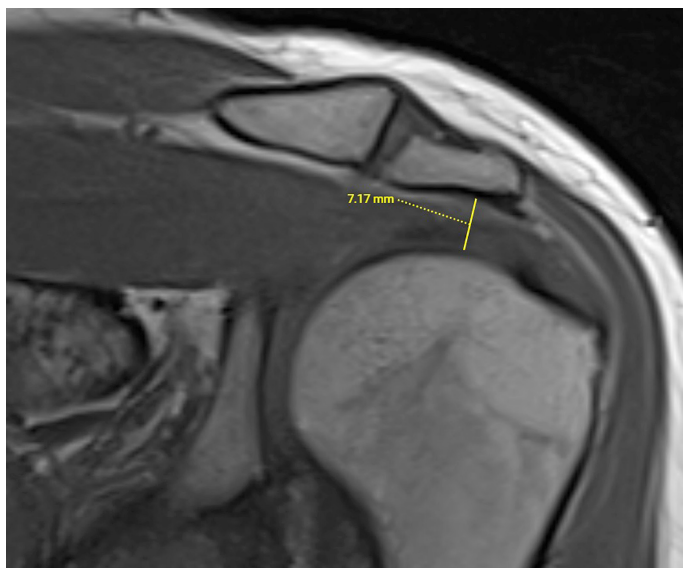
### Statistical Analysis

Statistical analyzes were performed using the International Business Machines (IBM®) Statistical Package for the Social Sciences (SPSS®) Statistics software for Windows, version 22.0 (IBM SPSS Corp.; Armonk, NY, USA). Frequency, percentage, mean, standard deviation, median, and minimum–maximum values were calculated. The parametric test procedures were applied after the quantitative values showed normal distribution in the Kolmogorov–Smirnov test. In this context, *t*-test in independent groups and Pearson correlation test were used to determine the relationships between patient groups classified regarding the Ellman's classification. The Kruskal–Wallis test was used for parameters where the number of people per group was below 30. The results were evaluated within the 95% CI, and the *P* < .05 value was considered to present the statistical significance.

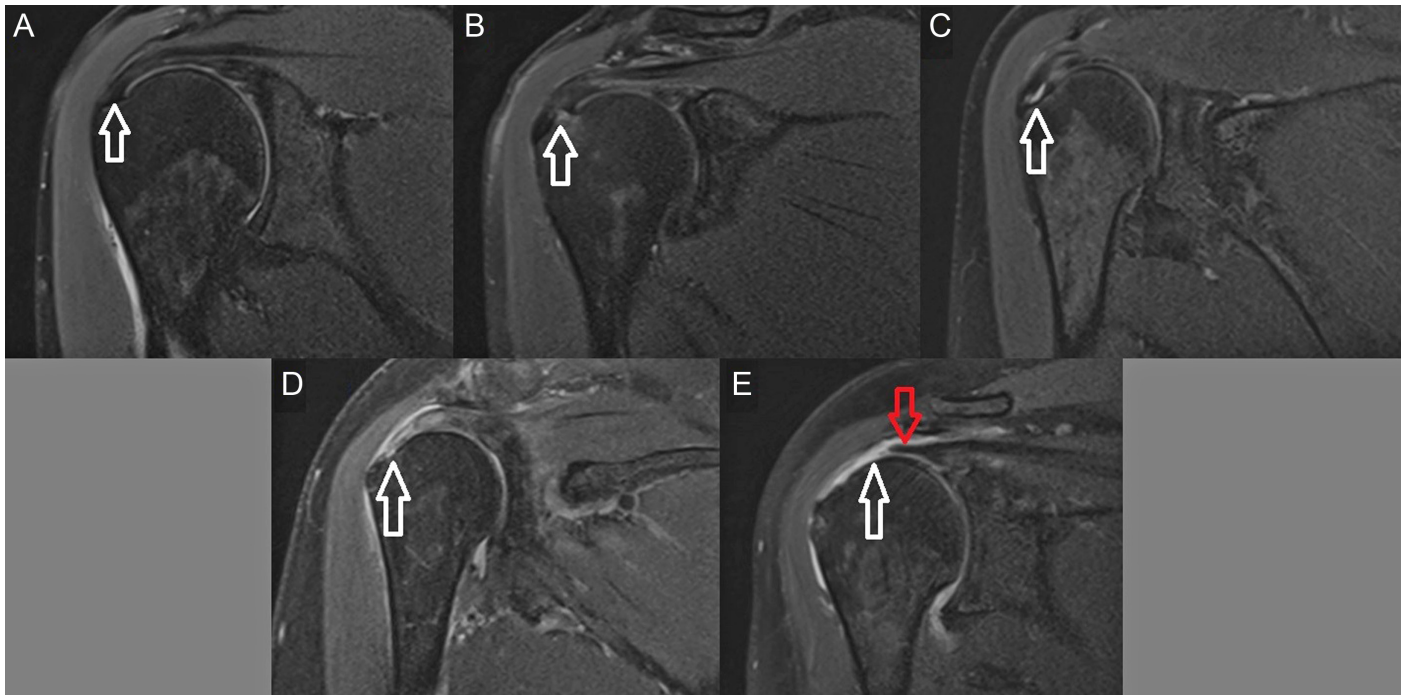
### RESULTS

In our study, 534 shoulder MRIs were scanned. As a result, 304 shoulder MRIs meeting the criteria were included in our study. Women comprised 61.8% (188/304), while men comprised 38.2% (116/304). The average age was 52 years, with the youngest being 19 and the oldest being 88. There was no significant correlation between age and AHI according to a Pearson correlation test (*P* = .056). AHI values were found to be significantly higher in men than in women (*P* = .015) (Table 1). The AHI measurements significantly differed between the control group and supraspinatus tendon injuries and the control group was observed with higher values (*P* = .003) (Table 2).

The patients without rotator cuff injuries constituted 41.4% (126/304) of the population included in the investigation. Those with tears in the isolated supraspinatus tendon comprised grade 1: 30.9% (94/304); grade 2: 6.6% (20/304); grade 3: 11.8% (36/304); and grade 4: 9.2% (28/304) of the patients' population included in the



**Figure 2.** 48-year-old female patient is shown on coronal T1-weighted magnetic resonance imaging sequence acromiohumeral interval, which is measured as the shortest interval extending from the lower cortical border of the acromion to the upper cortical edge of the humeral head.



**Figure 3.** An exemplary image of the integrity of the supraspinatus tendon in different individuals is shown in coronal fat-suppressed MRI sequences. A: The individual with normal integrity and signal of the supraspinatus muscle tendon is followed. B: A patient with grade 1 tear, low-grade partial thickness tears (< 3 mm deep or < 25% thickness) and increased signal intensity in the isolated supraspinatus tendon is followed. C: A patient with grade 2 tears, moderate partial thickness tears (3-6 mm deep or approximately 50% of the thickness of the tendon) and increased signal intensity in the isolated supraspinatus tendon is followed. D: A patient with grade 3 tear, partial tears of the bursal or articular surface with a high-grade partial thickness tear (> 6mm deep or more than half of the thickness of the tendon) and increased signal intensity in the isolated supraspinatus tendon is followed. E: A patient with grade 4 tear, complete or full thickness (100% thickness) tear, increased signal intensity and muscle retraction in the isolated supraspinatus tendon is being followed.

research (Table 3). The mean values of AHI measurements for controls, partial, and total supraspinatus tendon tears are presented in Table 4. A Dunn test revealed significantly lower AHI values for grade 4 patients than grades 1, 2, and 3 regarding Ellman's classification ( $P < .001$ ).

## DISCUSSION

During the abduction movement of the deltoid, the humeral head is pulled superiorly. The rotator cuff muscles prevent the humeral head from migrating to the proximal. If the rotator cuff muscles are torn, the humeral

head migrates superiorly on the deltoid side.<sup>1,16</sup> For the first time, Golding investigated the role of AHI in diagnosing by measuring AHI by radiography in 150 patients with healthy and injured shoulders. AHI values were found between 7 and 13 mm in those with an intact shoulder.<sup>5</sup>

Cotton and Rideout measured AHI in the intact and injured shoulders using radiological and pathological correlation with direct radiography. They defined AHI to present the distance from the inferior border of the acromion to the cortex of the humeral head. AHI ranged from 6 to 14 mm in those with intact rotator cuffs. They reported that it ranged from 1 to 4 mm in patients with full-thickness rotator cuff tears. However, the authors concluded that

**Table 1.** Demographic Data of the Population in the Study in Relationship with AHI Values

	n	Mean $\pm$ SD	P
<b>Age and AHI</b>			
Age (Total)	304	51.01 $\pm$ 14.37	.056*
<b>Gender and AHI</b>			
AHI (Males)	116	8,60 $\pm$ 1.50	<b>.015</b>
AHI (Females)	118	8.20 $\pm$ 1.44	

AHI, Acromiohumeral interval; SD, Standard deviation; \*, P value of the correlation between age and AHI.

**Table 2.** Acromiohumeral Interval Values in Patients With or Without Supraspinatus Tendon Tear

Patient groups	n	AHI (Mean $\pm$ SD)	P
Patients without tendon tear	126	8.66 $\pm$ 1.43 mm	<b>.003</b>
Patients with tendon tear (grade: 1-4)	178	8.15 $\pm$ 1.47 mm	<b>.003</b>

AHI, acromiohumeral interval.



**Table 3.** Acromiohumeral Interval Values According to Ellman’s Classification

Ellman’s Classification	n	AHI (mm)	
Control	126	Mean	8.66
		Median	8.63
		SD	1.43
		Minimum	5.28
		Maximum	14.05
Grade 1	94	Mean	8.48
		Median	8.40
		SD	1.18
		Minimum	5.88
		Maximum	11.67
Grade 2	20	Mean	8.70
		Median	8.64
		SD	1.19
		Minimum	6.65
		Maximum	11.86
Grade 3	36	Mean	8.35
		Median	8.46
		SD	1.24
		Minimum	5.62
		Maximum	10.86
Grade 4	28	Mean	6.36
		Median	6.81
		SD	1.59
		Minimum	2.62
		Maximum	8.72

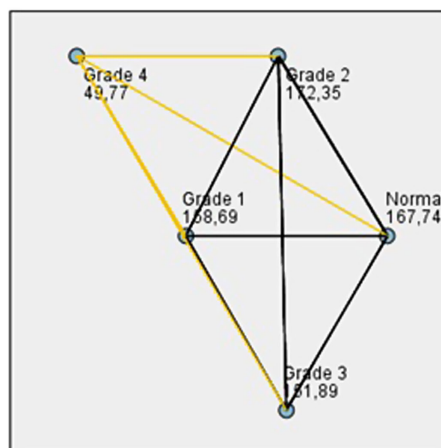
There is a significant relationship between Ellman grade and acromiohumeral interval ( $P < .001$ ). According to the results of the Dunn Test, which was conducted to determine between which groups this significant relationship is as follows: acromiohumeral interval measurements of the normal group are higher than grade 4; acromiohumeral interval measurements of the grade 1 group are higher than grade 4; acromiohumeral interval measurements of the grade 2 group are higher than grade 4; acromiohumeral interval measurements of grade 3 groups are higher than grade 4.

narrowing of the AHI was not a reliable sign for diagnosing a full-thickness rotator cuff tear, and those changes seen on plain radiographs gave little indication of the severity of the tear.<sup>1</sup>

Weiner and Macnab suggested that the leading cause of proximal migration of the humeral head was no other muscle to prevent the deltoid muscle from pulling up the humeral head due to a supraspinatus tear. Weiner and Macnab’s AHI measures 7-14 mm in healthy individuals without rotator cuff damage, while those with 5 mm or less AHI accepted it as a rotator cuff tear.<sup>1</sup>

Dunn Test

Pairwise Comparisons of Ellman



Each node shows the sample average rank of Ellman.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
Grade 4-Grade 3	102,121	22,149	4,611	,000	<0.001
Grade 4-Grade 1	108,918	18,925	5,755	,000	<0.001
Grade 4-Normal	117,970	18,365	6,424	,000	<0.001
Grade 4-Grade 2	122,582	25,735	4,763	,000	<0.001
Grade 3-Grade 1	6,797	17,228	,395	,693	1,000
Grade 3-Normal	15,849	16,612	,954	,340	1,000
Grade 3-Grade 2	20,461	24,514	,835	,404	1,000
Grade 1-Normal	9,052	11,980	,756	,450	1,000
Grade 1-Grade 2	-13,664	21,645	-,631	,528	1,000
Normal-Grade 2	-4,612	21,158	-,218	,827	1,000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

Hamada et al. proposed a classification system to understand the relationship between rCA severity and rotator cuff tears. They measured the AHI using radiography in patients with tears in the supraspinatus and infraspinatus muscles and confirmed by arthrography. They found a mean AHI of 4.4 mm in their study. They said that the long head of the biceps muscle tried to prevent the proximal migration of the humeral head against the function of the deltoid muscle in patients with rotator muscle tear, and the proximal migration of the humeral head was severe in cases with a tear of the long head of the biceps muscle.<sup>1,7,17-20</sup>

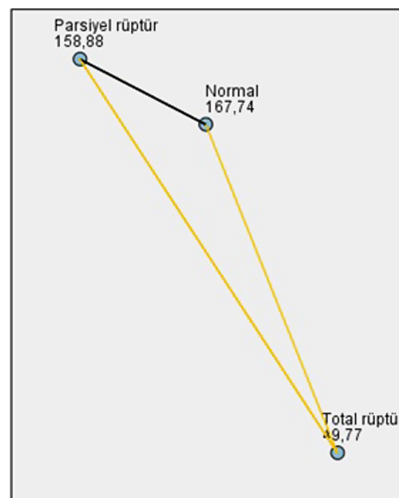
**Table 4.** Acromiohumeral Interval Values in Controls, Patients with Partial and Total Supraspinatus Tendon Tear

Patients	Acromiohumeral Interval (mm)	
Patients without tendon tear	Mean	8.66
	Median	8.63
	SD	1.43
	Minimum	5.28
	Maximum	14.05
Patients with tendon tear (Ellman's grades 1,2 and 3)	Mean	8.48
	Median	8.49
	SD	1.19
	Minimum	5.62
	Maximum	11.86
Patients with complete or full thickness tendon tears (Ellman's grade 4)	Mean	6.36
	Median	6.81
	SD	1.59
	Minimum	2.62
	Maximum	8.72

There is a significant relationship between Ellman grade and acromiohumeral interval ( $P < .001$ ). According to the results of the Dunn test, which was conducted to determine between which groups this significant relationship is as follows: acromiohumeral interval measurements of the normal group are higher than total rupture; acromiohumeral interval measurements of the partial rupture group are higher than the total rupture.

#### Dunn Test

#### Pairwise Comparisons of Ellman



Each node shows the sample average rank of Ellman.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
Total rüptür-Parsiyel rüptür	109,109	18,096	6,030	,000	<0.001
Total rüptür-Normal	117,970	18,365	6,424	,000	<0.001
Parsiyel rüptür-Normal	8,861	10,622	,834	,404	1,000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .05.

In our study, the mean AHI value was 8.3 mm in the total population, 8.6 mm in the non-ruptured group, and 8.15 mm in the ruptured group. Our study results were similar to Siow et al.'s study, which was performed on 257 patients' shoulder MRIs.<sup>7</sup> In our study, the AHI value of Elman grade 1, 2, 3 supraspinatus tendon tears in the normal group was found to be statistically higher than the AHI value of Elman grade 4 supraspinatus tendon tears. The control group's AHI value was higher than the group with Elman grade 1, 2, 3 supraspinatus tendon tears, but the difference was not statistically significant. The mean values for the total AHI of patients with Elman grade 1, 2, 3, and 4 supraspinatus tendon tears were significantly lower than the mean AHI value of the control group. This significance was dependent on the AHI values of Elman grade 4 supraspinatus tendon tears. There was no significant correlation between the AHI values in the control group and the group with Elman grade 1, 2, and 3 supraspinatus tendon tears.

Bezer et al., in their study with MRI in 2005, including ten patients with isolated supraspinatus tears, found that the humeral head migrated superiorly when the tear was present, and there was a decrease in AHI.<sup>1</sup> The result of the study was similar to this current study, but the number of patients was smaller than this current study.

In previous studies,<sup>1,7</sup> full-thickness tears of the supraspinatus, infraspinatus, and subscapularis tendons were all associated with decreased AHI. Similar to a previous study,<sup>7</sup> a statistically significant decrease in AHI was found in patients with full-thickness tears of the supraspinatus tendon. Our study included a larger patient population in detecting the relationship between the degree of tear and AHI in isolated supraspinatus tendon ruptures compared to previous studies.<sup>1,7,21</sup>

Siow et al., using shoulder MRI, found a statistically significant reduction in AHI in all full-thickness tears of the supraspinatus, infraspinatus, and subscapularis tendons in their study of 257 patients. Matthew Y. Siow et al. studied 58 subjects without a rotator cuff tear and 174 subjects with a supraspinatus injury and accompanying rotator cuff injury.<sup>7</sup> The study population was smaller than ours for the total population and the group with isolated supraspinatus injury.

In this current study, the mean AHI was 6.36 mm in patients with a complete or full-thickness tear (grade 4) in the supraspinatus tendon. In their study using radiography and MRI, Nadja Saupe et al. found that reduced acromio-humeral distance is a reliable sign of rotator cuff tear, similar to our study. Also, similar to our study, more than 90% of patients with AHI  $\leq$  7 mm showed a complete or full-thickness tear in the supraspinatus tendon (grade 4) in their study.<sup>22</sup>

There were limitations of our study to be discussed. Due to the retrospective nature of our study, the hospital records and radiological examination results were used to diagnose rotator cuff tears. Surgical outcomes of the operated patients would give more accurate results. Additionally, the relationship between tendon tears and muscle atrophy, fatty degeneration, or capsular injury was not taken into account for this study.

Historically, it has been known that tears in the rotator cuff muscles cause migration of the humerus and narrow the acromiohumeral distance. The results of this study underline this situation and additionally indicate that the patients with total rupture constitute this difference via Ellman's grading system.

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**Ethics Committee Approval:** Ethics committee approval was received for this study from the Erzincan Binali Yıldırım University Ethics Committee of Clinical Research Number: E-26447783-050.06.04-213515 Date: 02.11.2022.

**Informed Consent:** N/A. Permission was obtained from the hospital management to use patient data.

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Concept – Ş.K.; Design – Ş.K., V.K.; Supervision – V.K.; Resources – Ş.K., V.K., T.Ç.; Materials – Ş.K., T.Ç.; Data Collection and Processing – Ş.K., T.Ç.; Analysis and Interpretation – Ş.K., V.K.; Literature research – Ş.K., V.K., T.Ç.; Writing manuscripts – Ş.K.; Critical Review – V.K., T.Ç.

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