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Evaluating the strength of spinal and proximal girdle muscles in patients with axial spondyloarthritis: Correlation with activity, disability, and functionality

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Abstract

Aim: To compare the muscle strength of muscle groups in axial spondyloarthritis (axSpA) patients with the muscle powers of healthy volunteers and to examine the relationship of muscle strengths with disease activity, functionality, and disability.

Method: One hundred males (50 axSpA, 50 healthy) were included in the study. Bath Disease Activity Index (BASDAI), Functional Index (BASFI), and Health Assessment Questionnaire-Disability Index (HAQ-DI) scores were recorded. The maximum (max) and mean cervical flexion, extension, lateral flexion (CF, CE, CLF), truncal flexion, extension (TF, TE), root joint flexion, extension, abduction, internal and external rotation (SF, SE, SAB, SIR and SER for the shoulder; HF, HE, HAB, HIR and HER for the hip) muscle strengths of the patients in both groups were measured by a handheld dynamometer. Total muscle strength (CT, TT, ST, HT) was found according to the sum of the max and mean values for each region.

Results: All muscle strengths were lower in the axSpA group compared to the healthy volunteers. The symptom duration was found to have a weak-moderate negative correlation with CT, TT, ST, HT and all individual muscle strengths except for the TE, CF, HIR, and HER. BASDAI and HAQ-DI had weak-moderate negative correlations with HIR and HER. BASFI had a weak-moderate negative correlation with cervical measurements, TE, TF, SF, SER, SIR, and hip measurements.

Conclusion: All muscle strengths were lower in patients compared to healthy volunteers. Strengthening specific muscle groups for the desired goal can be a reasonable strategy. The study is prospectively registered and available at www.clinicaltrials.gov (NCT04435860).

KEYWORDS

ankylosing spondylitis, handheld dynamometer, manual muscle tester, muscle power

1 | INTRODUCTION

Axial spondyloarthritis (axSpA) refers to a group of systemic inflammatory rheumatic diseases that cause inflammation and stiffness, particularly in the spine, resulting in pain and limitations in physical efficiency as well as quality of life. The spine is primarily affected, and there is milder peripheral involvement.[1] Ankylosing spondylitis (AS) constitutes the prototype of these diseases.[2]

Decreased muscle strength has been reported in axial SpA patients compared to healthy controls.[3-5] In addition, some studies have found a decreased lean mass and increased fat mass in axSpA patients compared to controls.[5,6] AxSpA is a disease in which abnormal proinflammatory cytokines are secreted by innate immune cells, and the overexpression of tumor necrosis factor and other cytokines in this disease may cause the inhibition of the pathways that lead to muscle hypertrophy as well as the activation of proteolytic pathways in the muscle.[7-9] According to another perspective, inflammation, pain, joint stiffness, and enthesitis observed in axSpA patients may lead to inactivity, fatigue, and muscle weakness. Inactivity can cause the instability of the joint and can affect the muscle strength secondarily.[10] In the literature, the studies on muscle involvement in this patient group have focused on sarcopenia.[11,12] Although muscle mass is a factor affecting muscle strength, there may be factors other than muscle mass, which affect muscle strength and, therefore, functionality in inflammatory rheumatic diseases. Therefore, measuring muscle mass may be insufficient for determining how the functionality of the patient is affected.

The European League Against Rheumatism (EULAR) published physical activity recommendations for patients with SpA and focused on 4 types of activity (aerobics, flexibility, strengthening, and neuromotor exercises).[13] Also, physical activity is strongly recommended for active axSpA patients in the recommendations of the American College of Rheumatology (ACR)/Spondyloarthritis Research and Treatment Network (SPARTAN) in 2019.[14] The importance of exercise for axSpA in treatment is generally accepted; however, specific exercise programs have not been established for this disease in the literature. In these recommendations, there is no clear consensus on the most effective exercise type, the intensity and frequency of the exercises to be performed, and the muscle groups that should be addressed more intensely.[15,16]

In patients with SpA, the muscles, particularly the paravertebral muscles, are affected. Restriction in spinal movements is a well-known consequence of the disease process, and paravertebral muscle atrophy is observed due to this restriction.[17,18] In extraspinal involvement in this group of diseases, the root joints (shoulder and hip) are usually involved, and enthesitis is common in these joints.[19] Even though this involvement is assumed, no study has ever evaluated the strength of the main involved spine and root joint-related muscles neither separately nor in one study so far. In this context, our aim is to determine how the spine-related muscle groups and proximal girdle muscle strengths are affected in axSpA patients compared to healthy volunteers and to determine the relationship of the affected muscle groups with disease activity, functionality, and disability.

2 | METHODS

2.1 | Study design and patient enrollment

A total of 100 volunteers (50 with axSpA, 50 healthy), who presented to the outpatient clinic of the corresponding author, were included in this cross-sectional study. The study was approved by the institutional ethics committee (No: 08/115), and written informed consent was obtained from the participants. The study was carried out per the "Declaration of Helsinki, Ethical Principles for medical research involving human subjects." The study is prospectively registered and available at www.clinicaltrials.gov from 17 June, 2020 (ID: NCT04435860). Inclusion criteria for the axSpA group were as follows: (a) having been diagnosed with axSpA according to the 2010 criteria of the Assessment for Spondyloarthritis International Society (ASAS) (1); (b) to be of the male gender; (c) to be aged ≥ 18. Exclusion criteria were as follows: (a) presence of severe cardiac/pulmonary/renal disease; (b) accompanying fibromyalgia; (c) severe psychiatric disorder; (d) other diseases that may cause a restriction in the spine, pelvic, and shoulder girdle; (e) myopathy, neuropathy, and radiculopathy that may cause deficits in muscle strength; (f) use of high-dose corticosteroids; (g) endocrinological disorder (such as thyroid, parathyroid disorder); (h) malignancy. The control group was composed of healthy volunteers who did not meet the exclusion criteria. Since there was no similar study to the present study, effect sizes were calculated based on the data after the preliminary analysis of 10 patients for each group. A minimum of 50 patients was considered sufficient for each group (for maximum truncal extension strength [TE_{max}]), with 99% power, 0.91 standard effect size, and .05 significance. TE_{max} was selected for presenting the most significant dispersion.

Demographic data of patients and healthy individuals, laboratory parameters of patients were recorded by the same physician, and patients filled out clinical assessment questionnaires. Then, muscle strength measurements were made by a different evaluator. All evaluations were made on the same day. Data analysis and interpretation were performed by a 3rd physician.

2.2 | Clinical assessments

Bath Ankylosing Spondylitis Disease Activity Index (BASDAI), Bath Ankylosing Spondylitis Functional Index (BASFI), and Health Assessment Questionnaire-Disability Index (HAQ-DI) obtained from the patients were recorded. The BASDAI consists of a 0 through 10 scale with 6 questions.[20] On the other hand, BASFI examines the functional status of the patient by Numerical Rating Scale with 10 questions. The mean of the 10 answers yields the BASFI score, which is a value between 0 and 10.[21] A worsened patient condition

was indicated with a higher Bath index. HAQ-DI is a 20-item questionnaire in which daily life activities are examined and is generally used in rheumatic diseases. The mean of the responses is calculated, and the total score varies between 0 and 3. A high score indicates a high level of disability.[22]

2.3 | Muscle strength measurements

Muscle strength was measured with a manual muscle tester (Lafayette Instrument Company, Lafayette, IN, USA). This device can measure the maximum and the mean force in kilograms that can be applied in 10 seconds. The patients were asked to perform the desired movement with the maximum force they could apply for 10 seconds. To illustrate with an example, the supervisor described each movement on the patient once before the measurement and allowed the patient to rehearse. Next, the patient performed the movement. Measurements were made with 3 isometric contractions for each region, and there was a minimum of 30 seconds between measurements.[23] The maximum (max) and the mean value of 10 seconds were obtained for each measurement, and the highest of the 3 measurements was recorded. In order to determine the total max and mean muscle strength of the relevant joint region, the max and mean muscle strengths of all muscles in that region were summed up; thus, the HT, ST, TT, and CT values were determined. The mean of both sides was recorded in bilateral measurements, and the muscle strengths on the dominant side were tested in unilateral measurements.

Isometric muscle strength measurements of the cervical region were performed in a sitting position. The measurement cap of the dynamometer was placed in the middle of the forehead slightly above the eyebrows for CF, slightly above the external occipital protuberance for CE, and on the lateral aspect of the head above the ear for CLF[23] (Supplement 1). Isometric TF was measured by placing the patient in the supine position with the hip at 30 degrees and the knees in a straight position, and the measurement cap was placed on the sternum just below the suprasternal notch. Isometric TE was measured when the patient was in the prone position, with the hips and knees in the neutral position, and the measurement cap was placed at the level of the T4 vertebra[24] (Supplement 1). The measurement positions and methods, which were described by Katoh et al.,[25] were used for the measurements of the shoulder girdle, and the SF, SE, shoulder abduction (SAB), internal rotation (SIR) and external rotation (SER) values were obtained (Figure 1). The patient was placed in a sitting position with the hip and knee at 90 degrees, and the measurement cap was placed 5 cm above the patella on the anterior part of the distal thigh for HF. For HE, the measurement cap was placed 5 cm proximal to the knee behind the thigh when the patient was in the prone position. For hip abduction (HAB), the measurement was performed by placing the measurement cap on the lateral malleolus when the patient was in the supine position. For the internal rotation (HIR) and external rotation (HER) of the hip, the patient was placed in the prone position with the knees at 90 degrees of flexion. The cap was placed 5 cm proximal to the medial and lateral malleolus[26] (Supplement 2). The techniques described in the previous studies and proven for reliability with a handheld dynamometer were preferred for the measurements.

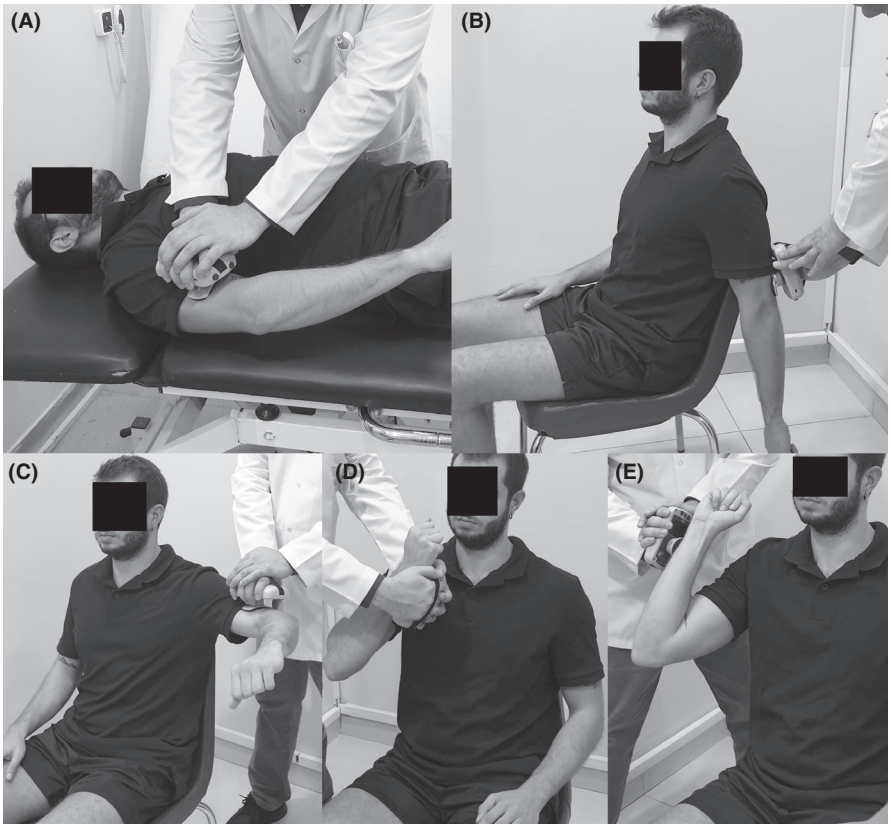

FIGURE 1 Shoulder girdle measurements (A) flexion, (B) extension, (C) abduction, (D) internal rotation, (E) external rotation

2.4 | Statistical analysis

The statistical analysis of the data was performed using the IBM Statistical Package for Social Sciences (SPSS) v23.0 (Armonk, NY, USA). The data distribution was analyzed for normality using the Shapiro-Wilk test. The descriptive statistics of the data were presented as mean ± SD (median [min-max]) for the continuous data and as frequency and percentage (n [%]) for categorical variables. In the comparison of 2 independent groups, the independent samples *t* test was used for normally distributed continuous data, and the Mann-Whitney *U* test was used for non-normally distributed continuous data. Pearson Chi-square and Fisher exact tests were used in the analysis of the categorical variables. Correlation analysis with Pearson correlation coefficient was used to determine the relationship between 2 independent variables in normally distributed continuous data. The relationships were interpreted as strongly, moderately, weakly, and negligibly correlated when $r \geq .70$, $r = .40$-$.69$, $r = .10$-$.39$, and $r \leq .10$, respectively.[27] The level of significance was determined as $\alpha = .05$.

3 | RESULTS

The study included 50 volunteers with axSpA (19 with non-radiographic axSpA and 31 with AS) and 50 healthy volunteers. The mean age was 39.88 ± 11.85 years for the axSpA group and 39.4 ± 10.52 years for the control group. Body mass index (BMI) was 25.95 ± 4.66 kg/m^2 in the patient group, while it was 26.2 ± 2.74 kg/m^2 in the control group. The demographic data and the data of the patient and control groups are presented in Table 1. There was no

TABLE 1 Demographic and clinical characteristics of the study population

	axSpA (50)	Control (50)	
	Mean ± SD Median (min-max)/ n (%)	Mean ± SD Median (min-max)/ n (%)	*P* value
Age, y	39.88 ± 11.85	39.4 ± 10.52	.831(t)
	39 (18-68)	38 (20-67)	
Height, cm	176.2 ± 6.72	176.96 ± 5.65	.542(t)
	175 (162-189)	176 (167-187)	
Weight, kg	80.58 ± 15.27	82.0 ± 9.1	.312(m)
	80 (50-123)	80 (63-103)	
BMI, kg/m^2	25.95 ± 4.66	26.2 ± 2.74	.746(t)
	25.75 (17.3-37.65)	25.73 (19.02-31.1)	
Educational status			
Primary school	9 (18.0%)	9 (18.0%)	.594**
Secondary school	10 (20.0%)	5 (10.0%)	
High school	17 (34.0%)	16 (32.0%)	
University	12 (24.0%)	16 (32.0%)	
Postgraduate	2 (4.0%)	4 (8.0%)	
Hand dominancy			
Right	47 (94.0%)	46 (92.0%)	1**
Left	3 (6.0%)	4 (8.0%)	
Smoking at anytime			
No	32 (64.0%)	36 (72.0%)	.52*
Yes	18 (36.0%)	14 (28.0%)	
Alcohol consumption			
No	44 (88.0%)	43 (86.0%)	1*
Yes	6 (12.0%)	7 (14.0%)	
Exercise habit			
None	23 (46.0%)	27 (54.0%)	.676*
1-2/wk	15 (30.0%)	14 (28.0%)	
≥3/wk	12 (24.0%)	9 (18.0%)	

Note: (t) independent samples *t* test; (m) Mann-Whitney *U* test.

axSpA, axial spondyloarthritis; BMI, body mass index.

*Pearson Chi-squared test.

**Fisher exact test.

TABLE 2 Comparison of two groups in terms of muscle strength

	Mean ± SD / Median (min-max)				Mean ± SD / Median (min-max)		
	axSpA (n = 50)	Control (n = 50)	*P* value		axSpA (n = 50)	Control (n = 50)	*P* value
HAB_{mean}	17.06 ± 6.47 16.7 (7.4-35.3)	21.04 ± 5.66 20.05 (11.5-35.4)	.002(m)	SER_{max}	16.62 ± 6.21 16.75 (6.1-30.7)	19.93 ± 4.67 20.25 (9.5-29.9)	.003(t)
HAB_{max}	21.58 ± 8.88 20.05 (8.6-44.7)	27.37 ± 8.17 25.7 (14.7-47.8)	.001(m)	SF_{mean}	15.03 ± 6.98 14.3 (4.6-30.2)	19.75 ± 6.97 19.95 (8-36)	.001(m)
HE_{mean}	18.21 ± 7.27 17.85 (6.8-32.5)	25.0 ± 6.2 25.75 (8.5-34.4)	<.001(t)	SF_{max}	19.4 ± 9.44 18.35 (5.4-42)	26.66 ± 10.03 28.3 (9.7-47.8)	.001(m)
HE_{max}	22.99 ± 10.69 20.4 (2.5-43.6)	32.45 ± 9.02 34.9 (9.8-51.3)	<.001(t)	SIR_{mean}	14.3 ± 5.44 14.2 (4.4-28.5)	16.41 ± 4.13 16.35 (9.3-27.6)	.032(t)
HER_{mean}	9.95 ± 3.34 9.6 (1.7-19)	11.94 ± 2.84 11.85 (6.6-18.2)	.002(t)	SIR_{max}	17.74 ± 6.46 17.35 (4.8-31.6)	20.98 ± 5.58 20.8 (12.3-35)	.008(t)
HER_{max}	12.11 ± 4.09 11.25 (3.5-25.2)	14.76 ± 3.46 14.4 (8.2-24.3)	.001(t)	CE_{mean}	8.63 ± 4.03 8.45 (0.4-17.7)	11.69 ± 3.64 11.15 (6-24.9)	<.001(m)
HF_{mean}	21.73 ± 10.68 18 (7.9-42.6)	28.37 ± 8.92 28.3 (9.6-48.7)	.001(m)	CE_{max}	10.85 ± 4.86 10.9 (3-22)	14.35 ± 4.34 14.1 (6.8-29.2)	<.001(m)
HF_{max}	28.27 ± 14.28 24.75 (8.9-54.5)	37.03 ± 12.09 37.3 (12.2-58.8)	.001(m)	CF_{mean}	8.82 ± 3.17 8.65 (3.8-15.3)	10.66 ± 2.92 10.2 (6.8-21)	.004(m)
HIR_{mean}	12.78 ± 3.98 11.9 (5.8-21.2)	14.89 ± 3.25 14.9 (8.1-21.1)	.005(t)	CF_{max}	10.68 ± 3.84 10.75 (4.5-18.2)	13.27 ± 3.7 12.55 (7.4-23.8)	.002(m)
HIR_{max}	15.7 ± 4.68 15 (6.8-23)	19.2 ± 4.65 19.05 (9.5-34.1)	.001(m)	CLF_{mean}	8.55 ± 3.4 8.1 (3.45-16.2)	11.14 ± 2.66 10.85 (6.6-21.15)	<.001(m)
SAB_{mean}	13.92 ± 5.34 14.1 (4.3-24.1)	19.1 ± 5.71 18.25 (8.3-32.4)	<.001(t)	CLF_{max}	10.32 ± 4.17 9.4 (4.2-20.35)	13.29 ± 3.24 12.68 (8.1-25.55)	<.001(m)
SAB_{max}	17.49 ± 6.75 17.95 (5.1-33.8)	24.6 ± 7.95 24.45 (11.9-42.4)	<.001(t)	TE_{mean}	15.17 ± 7.03 15.4 (2.4-28.5)	20.11 ± 4.63 20.05 (12.1-32.4)	<.001(m)
SE_{mean}	12.69 ± 4.49 12.55 (5-22.5)	16.51 ± 5.07 16.3 (7.5-31.2)	<.001(t)	TE_{max}	19.12 ± 9.54 17.4 (6.7-37.4)	25.48 ± 6.95 25.05 (9.9-42.3)	.001(m)
SER_{max}	16.32 ± 6.23 15.9 (6-28.7)	20.73 ± 6.44 20.25 (9.6-37.3)	.001(t)	TF_{mean}	15.51 ± 7.0 15 (4.3-28.3)	18.93 ± 5.07 19.25 (10.4-28)	.008(m)
SER_{mean}	13.54 ± 4.84 13.25 (5.1-23.7)	16.51 ± 3.75 17.05 (7.9-23.7)	.001(t)	TF_{max}	19.73 ± 9.61 18.8 (4.9-39.7)	25.06 ± 7.17 25.9 (12.4-39.8)	.002(m)

Note: (t): independent samples *t* test, (m): Mann-Whitney *U* test.

axSpA, axial spondyloarthritis; max, maximum; CE, cervical extension; CF, cervical flexion; CLF, cervical lateral flexion; HAB, hip abduction; HE, hip extension; HER, hip external rotation; HF, hip flexion; HIR, hip internal rotation; SAB, shoulder abduction; SE, shoulder extension; SER, shoulder external rotation; SF, shoulder flexion; SIR, shoulder internal rotation; TE, truncal extension; TF, truncal flexion.

significant difference between the 2 groups in terms of age, weight, height, BMI, educational status, hand dominancy, smoking and alcohol use, and exercise habits. The clinical features of the axSpA patients were as follows: the symptom duration (months) = 57.47 ± 90.73 (24 [3-360]), BASDAI = 4.24 ± 2.22 (4.35 [0-9.3]), BASFI = 2.47 ± 2.05 (2.15 [0-7.1]), HAQ-DI = 0.26 ± 0.24 (0.25 [0-1]), erythrocyte sedimentation rate (ESR) (mm) = 13.24 ± 13.72 (9.5 [2-60]) (N: 0-15) and C-reactive protein (CRP) (mg/L) = 13.13 ± 19.43 (5.11 [0.2-78]) (N: 0-5). Human leukocyte antigen-B27 was positive in 58% of the patients.

When the measurements of the muscle strengths of the control and axSpA groups were compared, a significant decrease was found in the axSpA group compared to the control in all muscle groups (Table 2). In terms of the total muscle strengths of the relevant regions, a significant decrease was found in the axSpA group compared to the control group (Table 3).

When the relationship of the total muscle strengths with laboratory tests was examined, no muscle group was related to ESR and CRP. Symptom duration was found to have a moderate negative correlation with ST_{max}, ST_{mean}, HT_{max} and HT_{mean} (r = −.4, −.42, −.4

TABLE 3 Comparison of total muscle strength according to regions

	Mean ± SD / Median (min-max)		
	axSpA (n = 50)	Control (n = 50)	*P* value
Hip $total_{mean}$	79.72 ± 28.24	101.24 ± 21.57	<.001(t)
	77.2 (38.1-135.9)	101.1 (46.2-147.3)	
Hip $total_{max}$	100.65 ± 37.74	130.8 ± 30.28	<.001(t)
	95.9 (44-175.4)	129.85 (56.7-193.1)	
Shoulder $total_{mean}$	69.48 ± 24.38	88.28 ± 23.14	<.001(t)
	71.15 (24.3-115.8)	90.05 (44-149.1)	
Shoulder $total_{max}$	87.56 ± 31.91	112.9 ± 31.27	<.001(t)
	86.8 (28.5-151.6)	112.45 (59.9-184.8)	
Cervical $total_{mean}$	26.01 ± 10.18	33.49 ± 8.21	<.001(m)
	24.5 (10.05-48.5)	32.03 (19.5-60.7)	
Cervical $total_{max}$	31.86 ± 12.32	40.9 ± 10.37	<.001(m)
	30.08 (13.75-59.15)	39.63 (23.2-73.9)	
Truncal $total_{mean}$	30.68 ± 13.47	39.04 ± 8.96	.002(m)
	29.1 (10.3-56)	39.95 (25.4-58.6)	
Truncal $total_{max}$	38.85 ± 18.52	50.54 ± 13.45	.001(m)
	35.95 (11.6-71.1)	51.1 (23.6-76.5)	

Note: (t) independent samples *t* test, (m) Mann-Whitney *U* test.
axSpA, axial spondyloarthritis; max, maximum.

TABLE 4 Correlations between clinical features and total muscle strengths

	r					
	ESR	CRP	Symptom duration	BASDAI	BASFI	HAQ-DI
TT_{max}	-.09	-.18	-.34*	-.19	-.41**	-.17
TT_{mean}	-.04	-.12	-.35*	-.2	-.4**	-.19
ST_{max}	.03	-.13	-.4**	-.16	-.32*	-.06
ST_{mean}	.05	-.11	-.42**	-.19	-.31*	-.09
HT_{max}	-.03	-.21	-.4**	-.21	-.43**	-.14
HT_{mean}	-.02	-.22	-.4**	-.24	-.45**	-.19
CT_{max}	.06	-.06	-.32*	-.23	-.35*	-.12
CT_{mean}	.05	-.07	-.31*	-.24	-.35*	-.13

Note: r, Pearson correlation test coefficient; ESR, erythrocyte sedimentation rate; CRP, C-reactive protein; max, maximum; TT, truncal total; ST, shoulder total; HT, hip total; CT, cervical total; BASDAI, Bath Ankylosing Spondylitis Disease Activity Index; BASFI, Bath Ankylosing Spondylitis Functional Index; HAQ-DI, Health Assessment Questionnaire-Disability Index.
*P value < .05.
**P value < .01.

and −.4, respectively); and a weak negative correlation with TT_{max}, TT_{mean}, CT_{max} and CT_{mean} (r = −.34, −.35, −.32 and −.31, respectively). In terms of clinical evaluation scales, BASFI was found to have a moderate negative correlation with TT_{max}, TT_{mean}, HT_{max}, and HT_{mean} (r = −.41, −.4, −.43 and −.45, respectively); and a weak negative correlation with ST_{max}, ST_{mean} CT_{max} and CT_{mean} (r = −.32, −.31, −.35 and −.35, respectively). BASDAI and HAQ-DI had no relationship with the total strength of any muscle groups (Table 4).

When the muscle groups were evaluated individually, no relationship was found in any muscle group with CRP and ESR. In terms of the symptom duration, TF_{max}, TF_{mean}, SF_{max} and SF_{mean} were correlated moderately and negatively, while all other shoulder girdle measurements were correlated weakly and negatively. No relationship was found with HIR_{max}, HIR_{mean}, HER_{max}, and HER_{mean}; however, a weak negative correlation was found with HE_{max} (r = −.39), and moderate negative correlations were found in all remaining

TABLE 5 Correlation between strength of individual muscle groups and clinical parameters

	r					
	ESR	CRP	Symptom duration	BASDAI	BASFI	HAQ-DI
TF_{max}	-.03	-.12	-.41**	-.14	-.36*	-.13
TF_{mean}	-.01	-.1	-.42**	-.18	-.37**	-.17
TE_{max}	-.15	-.24	-.25	-.22	-.44**	-.19
TE_{mean}	-.06	-.14	-.26	-.21	-.39**	-.2
SF_{max}	.01	-.13	-.4**	-.07	-.31*	-.02
SF_{mean}	0	-.15	-.43**	-.11	-.29*	-.05
SE_{max}	.06	-.1	-.34*	-.15	-.2	-.05
SE_{mean}	.08	-.09	-.36*	-.13	-.2	-.03
SAB_{max}	.08	-.05	-.37**	-.21	-.25	.03
SAB_{mean}	.06	-.03	-.38**	-.21	-.24	.01
SER_{max}	-.01	-.16	-.39**	-.18	-.36*	-.16
SER_{mean}	-.03	-.16	-.38**	-.21	-.36**	-.17
SIR_{max}	.01	-.17	-.29*	-.14	-.32*	-.11
SIR_{mean}	.11	-.05	-.32*	-.21	-.29*	-.2
HF_{max}	.01	-.14	-.41**	-.12	-.35*	-.05
HF_{mean}	.01	-.16	-.4**	-.14	-.38**	-.09
HE_{max}	-.11	-.2	-.39**	-.14	-.43**	-.06
HE_{mean}	-.08	-.19	-.4**	-.13	-.39**	-.07
HAB_{max}	0	-.18	-.51**	-.14	-.34*	-.08
HAB_{mean}	-.01	-.19	-.5**	-.2	-.37**	-.13
HIR_{max}	-.03	-.26	-.11	-.41**	-.46**	-.38**
HIR_{mean}	0	-.22	-.17	-.4**	-.46**	-.37**
HER_{max}	.05	-.26	0	-.34*	-.41**	-.38**
HER_{mean}	.02	-.35	-.08	-.41**	-.49**	-.45**
CF_{max}	-.01	-.09	-.22	-.19	-.37**	-.11
CF_{mean}	0	-.1	-.21	-.2	-.37**	-.13
CE_{max}	.04	-.05	-.29*	-.23	-.28	-.09
CE_{mean}	-.02	-.09	-.28	-.26	-.31*	-.11
CLF_{max}	.14	-.04	-.41**	-.25	-.38**	-.16
CLF_{mean}	.18	-.02	-.4**	-.22	-.35*	-.13

Note: r, Pearson correlation test coefficient; max, maximum; ESR, erythrocyte sedimentation rate; CRP, C-reactive protein; CE, cervical extension; CF, cervical flexion; CLF, cervical lateral flexion; HAB, hip abduction; HE, hip extension; HER, hip external rotation; HF, hip flexion; HIR, hip internal rotation; SAB, shoulder abduction; SE, shoulder extension; SER, shoulder external rotation; SF, shoulder flexion; SIR, shoulder internal rotation; TE, truncal extension; TF, truncal flexion; BASDAI, Bath Ankylosing Spondylitis Disease Activity Index; BASFI, Bath Ankylosing Spondylitis Functional Index; HAQ-DI, Health Assessment Questionnaire-Disability Index.

*P value < .05.

**P value < .01.

measurements of the hip. Also, symptom duration had a negative and moderate correlation with CLF_{max} and CLF_{mean}, and a weak negative correlation with CE_{max}. Regarding the relationship with BASDAI, a moderate negative relationship was found with HIR_{max}, $HIR_{mean,}$ and HER_{mean}, and a weak negative relationship was found with HER_{max}. BASFI had a moderate negative correlation with the TE_{max}, and a weak correlation with the remaining truncal muscle measurements. BASFI was determined to have a weak and negative correlation with flexor, internal rotator, and external rotator muscles of the shoulder girdle; however, no correlation was found with extensor and abductor muscles. A moderate negative correlation was determined between BASFI and HE_{max}, HIR_{max}, HIR_{mean}, HER_{max}, and HER_{mean} in the hip girdle, while weak and negative correlations were determined with other hip-related muscle groups.

BASFI had a weak negative correlation with CF_{max}, CF_{mean}, CE_{mean}, $CLF_{max,}$ and CLF_{mean} in the cervical region, and there was no correlation with CE_{max}. HAQ-DI was found to have a weak negative correlation with only HIR_{max}, HIR_{mean}, and HER_{max} and a moderate negative correlation with HER_{mean} (Table 5).

4 | DISCUSSION

Inflammation is the primary mechanism in patients with axSpA, and it leads to the loss of skeletal muscle secondarily by causing pain and stiffness.[5] It has been suggested that muscle strength in patients with axSpA would decrease due to the inflammatory process; however, the muscle strengths associated with the main involved regions have not been evaluated in a single study. Recommendations of exercise made on this matter are far from the specifications suggesting the effects of the strengths of individual muscle groups on disease parameters. Some of the studies conducted with patients with axSpA have evaluated muscle mass, namely sarcopenia, rather than muscle strength. In various studies, it has been found that sarcopenia is increased in AS patients.[11,12] In these studies, methods such as skeletal muscle index were used in the evaluation of sarcopenia.[28] These types of measurement methods are far from evaluating the muscle groups that are affected and determining the muscles that should be included in the strengthening program. It is difficult to determine the muscles that the muscle power distribution is in favor of and against in the total muscle mass. For this reason, we found it more appropriate to measure the muscle strengths of the muscle groups that could be measured objectively by handheld dynamometer; and we excluded females for the uniformity of the groups. We found that both the specific muscle groups and the total muscle strengths of the truncal and cervical muscles and root joints we measured were lower in patients with axSpA compared to the healthy volunteers. We found negative weak-moderate correlations between total muscle strengths and BASFI. Also, we determined weak-moderate correlations between individual muscle strengths and BASDAI, BASFI, and HAQ-DI.

Root joint involvement has been found to be effective upon functionality in patients with axSpA. It was observed that patients with clinical or radiological involvement in the hip joint had worse BASFI values.[29] In fact, BASFI does not contain questions about the hip joint directly; however, it is believed that the involvement of this joint indirectly affects the mobility of the spine and decreases spinal mobility.[30] One study suggested that hip involvement may reduce functional limitation more than spinal involvement by reducing the compensation of impaired spinal mobility.[31] With a similar mechanism, it can be thought that the shoulder girdle should be used more effectively to compensate for the limitation of motion in the thoracic and cervical regions. However, studies on how the muscle strength of the shoulder girdle is affected in patients with axSpA are limited. Hagberg et al.[32] compared the isometric maximum flexion muscle strength of the shoulder at 90 degrees with a strain gage instrument in 8 patients with AS and 10 healthy volunteers in their study, and they found no significant difference. In contrast to that study, we found a decreased muscle strength in patients with axSpA compared to the healthy volunteers in terms of the maximum shoulder flexion. We also found a significant decrease in muscle strengths of other shoulder girdle movements and in the total muscle strength of the shoulder. We observed this decrease both in maximum muscle strength and in the mean muscle strength that can be applied for 10 seconds. According to our results, there was also a weak negative correlation between functionality and total muscle strength of the shoulder.

Limitations of functionality in the hip and shoulder girdle can lead to decreased quality of life and loss of workforce.[30] In our study, weak-moderate correlations were found between hip girdle muscles on BASFI, supporting this statement. In the shoulder girdle muscles, functionality was weakly associated with flexors, internal and external rotators. These results may be obtained due to the fact that BASFI contained questions addressing all muscle groups of hip girdle such as leaning forward, getting up from the ground, walking, as well as the questions addressing flexor and rotator muscle groups of the shoulder girdle such as wearing socks and lying on a shelf. Nevertheless, it may be argued that priority should be given to these muscle groups, which are used more in functionality while strengthening root joints in patients. Interestingly, a negative and moderate relationship was found between BASDAI and the internal and external rotators of the hip. It appeared that only this muscle group was observed to be affected due to the increased disease activity. Further, only the same muscle group seemed to be related to HAQ-DI, which was an indicator of disability. The critical role of the hip rotators in daily living activities and walking has been determined.[33] Nonetheless, why other muscle groups do not exhibit this relationship is a question worth investigating.

In their study, Akgul et al.[34] evaluated the fatty degeneration in the paravertebral muscles semi-quantitatively by magnetic resonance imaging in 36 patients with axSpA (14 with non-radiographic axSpA and 22 with AS). They concluded that there was increased fatty degeneration in the paravertebral muscles of the patients with AS with longer symptom duration compared to patients with non-radiographic axSpA. In our study, we found that symptom duration had a moderate correlation with truncal flexion and cervical lateral flexion muscle strength. Although the mentioned study did not evaluate muscle strength as in our study, it is an important study in terms of demonstrating the histological influence of the paravertebral muscles, and the reflection of these findings to the clinic was also observed in the results of our study. The weak-moderate correlation of cervical and truncal muscle strengths with functionality reveals the importance of these muscle groups in patients with axSpA. The relationship between the duration of symptoms and especially hip, shoulder, and truncal flexors may be manifestations of the postural disorder that develops in the flexor direction on muscle strength.

Sahin et al.[3,4] determined the flexor and extensor muscle strengths of the ankle and knee in 26 patients with AS and 26

healthy controls using an isokinetic dynamometer. They found that muscle strength was lower in patients with axSpA compared to the control group. They found no correlation between muscle strength of the knee and BASFI; however, they found a low correlation between muscle strength of the ankle and BASFI. Although knee and ankle muscle strengths are important for walking, walking alone may not be suitable for evaluating everyday life activities and functionality. In addition, since the patients with axSpA have axial and root joint involvement rather than peripheral lower extremity muscle involvement, it seems more logical to evaluate these muscle groups. In this context, we compared muscle strengths in muscle groups related to the cervical, truncal, and root joints with healthy volunteers in our study, and we found a significant decrease in all muscle groups. We also found weak-moderate correlations with BASFI in various muscle groups we evaluated.

There were some limitations in our study. First of all, peripheral muscle involvement was not examined in this study. Considering that the peripheral joints were affected less than the axial spine without causing deformity in most of the patients, it was thought that the priority was to examine the axial and root joint involvement. However, the effect of particularly the upper extremity muscle strength should be analyzed in future studies. In addition, the lumbar muscle strength was not studied due to the technical limitation of the handheld dynamometer and the inseparability of the effect of the hip girdle. Further, the effects of the hip and shoulder adductors were not studied due to reliability concerns and technical difficulty. Nevertheless, even though disease activity scores varied from 0 to 9.3, the mean BASDAI score was 4.24 ± 2.22, indicating a high disease activity. A future study in patients with low disease activity may be conducted. Also, we did not seek the relationship between enthesitis and strength of related muscles, which may be subject to another study. Finally, the weak-moderate correlations found in the study may seem to be low; however, these correlations are considered to be clinically significant since functionality and disability are affected by many factors.

In conclusion, the strengths of the cervical, truncal, shoulder, and hip joint-related muscles were found to be decreased in patients with axSpA compared to healthy individuals. As the symptom duration increased, all spine and root joint muscles examined were affected at a low or moderate level, except for truncal extensors, cervical flexors, and the internal and external rotators of the hip. Disease activity and level of disability were found to be associated with the rotator muscles of the hip. Although functionality was found to be associated with many muscle strengths examined, it was mostly found to be associated with TE_{max}, HE_{max}, and the rotators of the hip, and not with shoulder extensors and abductors among the muscles that were evaluated. According to the data of our study, muscle strengthening exercises should be an essential part of the treatment in this patient group. In addition, strengthening specific muscle groups for the desired goal can be a reasonable strategy. Broader studies are needed on this subject matter.

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CONFLICT OF INTEREST

The authors declare they have no conflict of interest.

AUTHOR CONTRIBUTIONS

Conceptualization: OVY, OEI; methodology: OVY, FB, OEI; formal analysis and investigation: OVY, MK, EK; writing - original draft preparation: OVY, MK, EK; writing - review and editing: FB, TA; supervision: OVY, TA. All authors have read and approved the final manuscript.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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