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Research Article / Araştırma Makalesi

Investigating the relationship between proprioception and muscle strength in individuals with shoulder impingement syndrome

Omuz sıkışma sendromu olan bireylerde propriyosepsiyon duyusu ve kas kuvveti arasındaki ilişkinin incelenmesi

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ABSTRACT

Objective: The aim of this study was to examine the relationship between proprioceptive sense and muscle strength in individuals with shoulder impingement syndrome.

Materials and Methods: The study included 45 participants (15 males and 30 females, aged 22-74) with shoulder impingement syndrome and pain for at least 1 month. The study assessed shoulder proprioception on both the painful and non-painful sides using the Goniometer Pro application and shoulder muscle strength with the K-Force hand dynamometer. Comparisons of proprioception and muscle strength between both sides were made using the paired sample t-test for parametric data and the Wilcoxon rank-sum test for non-parametric data. The relationship between proprioception and muscle strength was analyzed using Pearson's correlation for parametric data and Spearman's rank correlation for non-parametric data. Results were considered significant at 0.05 level.

Results: A significant difference was found between the proprioception and muscle strength of the painful and non-painful shoulders; the painful side exhibited lower proprioception and muscle strength. Significant correlations were observed between proprioception and muscle strength of both the painful and non-painful sides. These correlations were stronger on the painless side across various parameters. Proprioception during 15° and 30° internal rotation and 15° external rotation were more closely related to muscle strength on the non-painful side. Meanwhile, proprioception during 30° flexion and 30° abduction were more closely associated with muscle strength on the painful side.

Conclusions: Shoulder impingement syndrome can impact the proprioception and muscle strength, leading to a decline in function. In the case of shoulder impingement, proprioception is more related to shoulder flexion and abduction muscle strength. We recommend incorporating exercises that enhance proprioception, particularly those that strengthen flexion and abduction muscles, in the rehabilitation of shoulder impingement syndrome.

Keywords: *Impingement syndrome, muscle strength, proprioception, shoulder*

ÖZ

Amaç: Bu çalışmanın amacı omuz sıkışma sendromu olan bireylerde propriyosepsiyon duyusu ve kas kuvveti arasındaki ilişkiyi incelemektir.

Gereç ve Yöntemler: Araştırmaya omuz sıkışma sendromu ve en az 1 aydır ağrısı olan 45 (22-74 yaş aralığında 15 erkek, 30 kadın) birey dahil edildi. Araştırmada bireylerin ağrılı ve ağrısız taraf omuz propriyosepsiyon duyusu Goniometer Pro uygulaması, kas kuvveti ise K-Force el dinamometresi ile değerlendirildi. İki taraf propriyosepsiyon duyusu ve kas kuvveti parametrik verilerde "paired sample t" testi, non-parametrik verilerde Wilcoxon sıra sayıları testi ile karşılaştırıldı. Propriyosepsiyon duyusu ve kas kuvveti arasındaki ilişki parametrik verilerde Pearson korelasyon analizi, non-parametrik verilerde Spearman'ın sıra sayıları korelasyon katsayısı ile incelendi. Sonuçlar 0,05 anlamlılık düzeyinde değerlendirildi.

Bulgular: Ağrılı ve ağrısız taraf omuz propriyosepsiyon duyusu ile omuz kas kuvveti arasında anlamlı fark olduğu; ağrılı taraf propriyosepsiyon duyusu ve kas kuvvetinin daha az olduğu belirlendi. Ağrılı ve ağrısız taraf propriyosepsiyon duyusu ile kas kuvveti arasında anlamlı ilişkiler olduğu saptandı. Bu ilişkilerin farklı parametrelerde ağrısız tarafta daha fazla olduğu bulundu. Ağrısız tarafta 15° ve 30° internal ve 15° eksternal rotasyonda propriyosepsiyon duyusunun kas kuvveti ile daha ilişkili olduğu belirlendi. Ağrılı tarafta ise 30° fleksiyon ve 30° abdüksiyonda propriyosepsiyon duyusunun kas kuvveti ile daha ilişkili olduğu saptandı.

Sonuç: Omuz sıkışma sendromu propriyosepsiyon duyusu ve kas kuvvetininin azalmasına yol açabilir. Omuz sıkışma sendromunda propriyosepsiyon duyusu omuz fleksiyon ve abdüksiyon kas kuvveti ile daha ilişkilidir. Omuz sıkışma sendromunun rehabilitasyonunda propriyosepsiyon ve özellikle fleksiyon ve abdüksiyon kas kuvvetini arttırmaya yönelik uygulamaların eklenmesini önermekteyiz.

Anahtar Sözcükler: *Omuz sıkışma sendromu, kas kuvveti, omuz, propriyosepsiyon duyusu*

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INTRODUCTION

Shoulder impingement syndrome involves the compression of rotator cuff structures, the long head of the biceps tendon, and the bursa beneath the coracoacromial arch during arm elevation, making it a prevalent health issue. People with this condition typically experience shoulder pain and a restricted range of motion, which diminishes their functional abilities. The primary factors contributing to impingement syndrome include inflammation of the subacromial bursa and rotator cuff muscles, tension in the posterior capsule, alterations in scapular positioning and posture, and rotator cuff muscle weakness (1-3). Research indicates that individuals with shoulder impingement syndrome exhibit decreased muscle strength compared to their unaffected side and healthy controls (1,3-5).

Proprioception, the awareness of the relative positions and movements of body parts that aids in shoulder stability and coordination, is believed to be linked to impingement syndrome (1,6-8). Diminished proprioception is associated with various shoulder injuries, including instability, impingement, rotator cuff disorders, and adhesive capsulitis (8). Studies suggest that patients with impingement syndrome experience a reduction in proprioceptive ability.

The relationship between proprioceptive sense and muscle strength has been extensively studied, particularly in the hip, knee, and ankle joints. These studies have established a correlation between proprioceptive acuity and muscle strength, demonstrating an enhancement in proprioception with increased muscle strength (9-11). However, most of this research has focused on the lower extremities (9-11). The impact of proprioception on shoulder disorders and its association with muscle strength remains understudied. Existing research primarily examines conditions such as shoulder instability, reverse shoulder arthroplasty, rotator cuff tears, idiopathic frozen shoulder, and subacromial impingement syndrome (6,12,13).

Moreover, while these studies primarily assess shoulder rotation-focusing on internal and external rotation proprioception-investigations into shoulder flexion and abduction are limited (14-16). Examining proprioception in shoulder flexion and abduction could provide valuable insights into functional movement patterns and inform targeted rehabilitation strategies. By incorporating assessments of flexion and abduction, this study takes a more comprehensive approach to understanding shoulder proprioception beyond the commonly studied rotational movements.

Muscle strength and proprioception are intrinsically related, with increased strength often leading to improved proprioception. This improvement enhances awareness of the body's spatial positioning, as stronger muscles provide greater sensory feedback to the nervous system regarding joint position and motion. Expanding upon this relationship in the shoulder, particularly in individuals with shoulder impingement syndrome, is crucial for optimizing rehabilitation strategies. This study aims to bridge that gap by investigating the relationship between shoulder proprioception and muscle strength in affected individuals.

MATERIAL and METHODS

The study included 45 volunteers (15 males and 30 females) aged between 22 and 74 from Ankara Bilkent City Hospital's Physiotherapy and Rehabilitation Clinic, all diagnosed with shoulder impingement by a physician. A priori power analysis using the G*Power 3.1.9.4 program determined the required sample size. With an effect size of 0.4 (medium), a power of 0.80, and a significance level of 0.05, the study required at least 44 participants (17).

The inclusion criteria were: a physician's diagnosis of shoulder impingement,
absence of additional shoulder discomfort, labral tears, systemic diseases, or other health issues, willingness to comply with study parameters, ability to perform the necessary tests, and consent to participate. The exclusion criteria included: failure to meet the inclusion criteria, acute or chronic neurological/orthopedic conditions affecting the upper extremity, previous upper extremity surgery, limitations in active or passive joint movements, and a diagnosis of bilateral shoulder impingement.

Ethics Committee approval was obtained from Ankara Yildirim Beyazit University's Health Sciences Institute (14.06.2023/06-261) before the commencement of the study. Participants received both verbal and written information about the study's purpose and procedures, and those who consented signed a voluntary consent agreement. The study was conducted in accordance with the 2013 Declaration of Helsinki.

Information regarding the study's inclusion criteria was obtained through required imaging studies conducted by a physician and evaluation questionnaires completed by the participants.

Study Procedure

All assessments were conducted on the same day. Before the evaluations, each participant's passive range of motion was measured. Demographic information was recorded for participants who had no passive range of motion restrictions and met the study's inclusion criteria.

influence on the proprioception assessment, muscle strength was always measured last.

Evaluation of Shoulder Proprioceptive Sense

The inclinometer application (Goniometer Pro, 5fuf5 USA), a smartphone app, was used to evaluate shoulder proprioception (18,19). Its validity and reliability have been established (19). To assess shoulder proprioception, an active repositioning test involving flexion, abduction, and both external and internal rotation movements was conducted. Measurements of shoulder flexion and abduction at 30, 60, 90, and 120 degrees, as well as external and internal rotation at 15, 30, and 45 degrees, were taken while the individual was seated in an armless chair or lying on a stretcher, respectively. Three repetitions were performed, and the average value was used for statistical analysis (6). Before each assessment, the researcher determined the target angle, which the individual felt with their eyes closed. The individual then actively replicated the movement to match the angle, indicating completion by saying "here." Each angle measurement was preceded by an explanation to the participant. A 10-second rest was provided after each measurement. During the assessment, the smartphone was fixed to the patient's arm using Velcro tape. Measurements were taken on both the impinged and non-impinged (painless) sides, starting with the painless side. The recorded measurement value was noted as angle.

Evaluation of Shoulder Muscles Strength

Shoulder muscle strength was assessed using a K-Force hand dynamometer (Kinvent, Montpellier, France), which exhibits excellent reliability and validity in muscle strength evaluation. Measurements were conducted in accordance with the manual muscle strength measurement guidelines (20). The researcher first demonstrated the movement to ensure the correct angle before the participant replicated it. Measurements were taken three times after a practice trial, and the average was calculated. If the measurements varied by more than 10%, an additional measurement was taken. A 10-second rest was provided between each measurement, and the measurement value was recorded in Newtons.

Shoulder flexion strength: The participant was seated upright and asked to perform 90° shoulder flexion with the palm facing downwards. The measurement was made by applying force in the opposite direction along the humerus while the participant resisted (Figure 1).

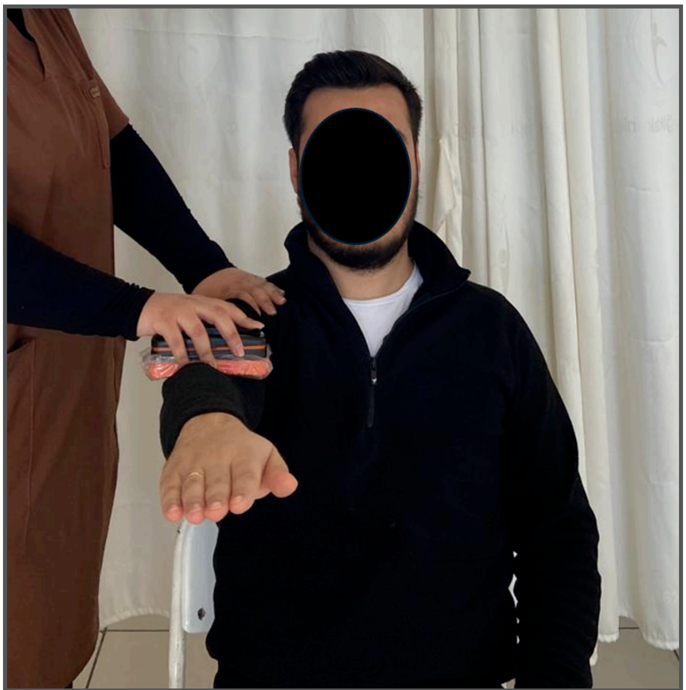

Figure 1. Shoulder flexion strength

Shoulder hyperextension strength: While in the prone position, the participant was instructed to hyperextend the arm. The measurement was made by applying force downwards at the distal part of the elbow joint while the participant resisted (Figure 2).

Figure 2. Shoulder hyperextension strength

Shoulder abduction strength: While seated upright, the participant was asked to perform 90° shoulder abduction. The measurement was made by applying force at the distal elbow joint in the direction of shoulder abduction while the participant resisted (Figure 3).

Figure 3. Shoulder abduction strength

Shoulder horizontal adduction strength: The participant was instructed to pull their hand towards the opposite shoulder while the arm was in 90° abduction in a supine position. The measurement was made by applying force outward from the inner surface of the humerus while the participant resisted (Figure 4).

Figure 4. Shoulder horizontal adduction strength

Shoulder horizontal abduction strength: The participant was positioned prone with the forearm off the bed edge in 90° shoulder abduction, perpendicular to the ground from the elbow. The participant was instructed to move the arm laterally after their scapula was stabilized by the researcher. The measurement was made by applying force downward at the distal elbow joint while the participant resisted (Figure 5).

Figure 5. Shoulder horizontal abduction strength

Shoulder external rotation strength: The participant was asked to perform an external rotation movement while the shoulder was in 90° abduction, the elbow in 90° flexion, and the hand in a neutral position. The measurement was made by applying force in the opposite direction from the distal part of the wrist while the participant resisted (Figure 6).

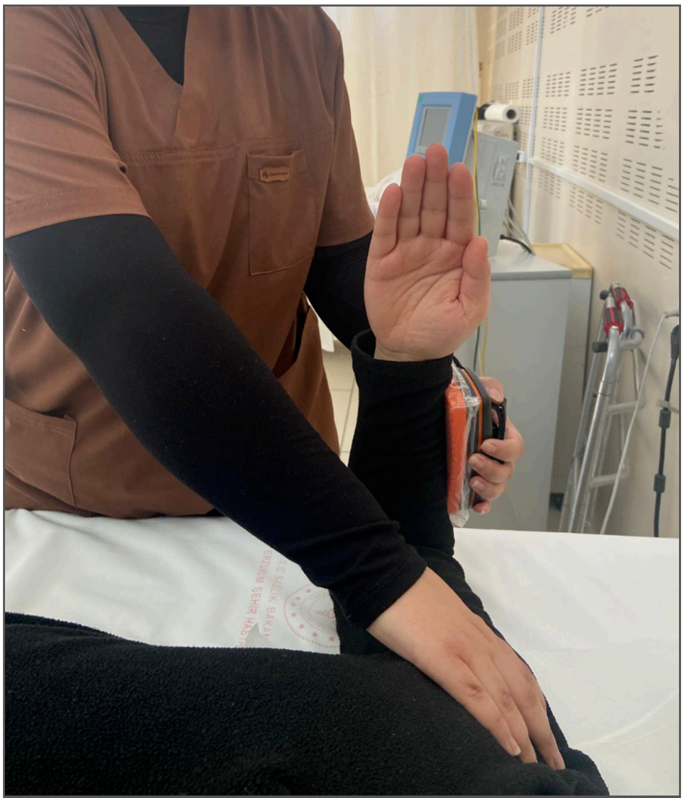

Figure 6. Shoulder external rotation strength

Shoulder internal rotation strength: The participant was asked to perform the internal rotation movement while lying supine, with the shoulder abducted at 90°, the elbow flexed at 90°, and the hand in a neutral position. The measurement was made by applying force in the opposite direction from the distal part of the wrist while the participant resisted (21) (Figure 7).

Statistical Analysis

The data obtained from this study were evaluated using the SPSS (Statistical Package for the Social Sciences) program, providing the mean, standard deviation, and minimum-maximum values for the variables. The Shapiro-Wilk test was used to assess the normality of the data distribution. For normally distributed data, comparisons between the painful and painless sides were made using the paired sample t-test, while the Wilcoxon signed-rank test was applied for non-normally distributed data. The relationship between shoulder proprioception and muscle strength was assessed using Pearson correlation analysis for normally distributed data and Spearman correlation analysis for non-normally distributed data. Correlation strengths were classified as follows: 0.2-0.5 indicating a weak relationship, 0.5-0.8 indicating a moderate relationship, and 0.8 and above indicating a strong relationship (22). The results were evaluated at a significance level of 0.05.

Figure 7. Shoulder internal rotation strength

RESULTS

The study included 45 participants. Demographic data and pain duration of the participants are presented in Table 1. The average body weight of the participants was 72.36±14.73 kg, the average height was 165.31±9.34 cm, the average BMI was 26.60±5.69 kg/m², and the average age was 51±15 years. The duration of pain among participants ranged from 1 to 36 months (Table 1).

Table 1. Demographic data, pain duration, and mean values of shoulder proprioception and muscle strength (n=45)

Variables	Mean±SD	Min-Max
Weight (kg)	72.36±14.73	42.00-100.00
Height (cm)	165.31±9.34	150.00-188.00
BMI (kg/m²)	26.60±5.69	14.69-36.73
Age (years)	51±15	22-74
Pain duration (months)	8±7	1-36

Mean±SD: Mean ± Standard deviation, Min-Max: Minimum-Maximum, kg: kilogram, cm: centimetre, m: metre

A comparison of proprioception and muscle strength in the painful and non-painful shoulders is provided in Table 2. Proprioception was found to be impaired in the painful shoulder during 30° and 60° flexion, 30° and 60° abduction, and 15°, 30°, and 45° internal and external rotation movements (p<0.05). No significant difference in proprioception was observed during 90° and 120° flexion and abduction movements (p>0.05). Muscle strength for flexion, abduction, hyperextension, horizontal abduction, horizontal adduction, internal rotation, and external rotation was all found to be lower in the painful shoulder (p<0.05) (Table 2).

Table 3 presents the relationship between the non-painful side's proprioception and muscle strength. A weak negative relationship was observed between 30° flexion proprioception and muscle strength in flexion (-0.449) and hyperextension (-0.386) (p = 0.002, 0.009). A weak negative correlation was noted between 30° abduction proprioception and muscle strength in flexion (-0.337), hyperextension (-0.351), abduction (-0.404), and internal rotation (-0.316) (p = 0.024, 0.018, 0.006, 0.035, respectively). Similarly, a weak negative correlation was found between 60° abduction proprioception and muscle strength in flexion (-0.307) and internal rotation (-0.355) (p = 0.04, 0.017). A weak negative correlation was also identified between 15° internal rotation proprioception and muscle strength in flexion (-0.435), hyperextension (-0.339), abduction (-0.334), horizontal abduction (-0.342), and internal rotation (-0.457) (p = 0.003, 0.023, 0.025, 0.021, 0.002, respectively). For 30° internal rotation proprioception, a weak negative correlation was found with muscle strength in flexion (-0.477), abduction (-0.348), horizontal adduction (-0.411), and internal rotation (-0.382) (p < 0.001, 0.019, 0.015, 0.01, respectively). A weak negative correlation was observed between 45° internal rotation proprioception and flexion muscle strength (-0.405) (p = 0.006). Furthermore, there was a negative correlation between 15° external rotation proprioception and muscle strength in flexion (-0.631), hyperextension (-0.433), abduction (-0.444), horizontal abduction (-0.373), horizontal adduction (-0.509), internal rotation (-0.498), and external rotation (-0.302) (p < 0.001, 0.003, 0.002, 0.012, < 0.001, < 0.001, 0.04, respectively). Lastly, a negative correlation was also established between 30° external rotation proprioception and muscle strength in flexion (-0.534) and internal rotation (-0.327) (p < 0.01, 0.028, respectively) (Table 3).

Table 2. Comparison of shoulder proprioception and muscle strength in painful and non-painful sides

Variables		Affected side Mean±SD	Unaffected side Mean±SD	p
Proprioception (°)	*30° Flexion*	36.87±5.99	31.90±2.52	**<0.01[a]**
	60° Flexion	63.96±5.35	60.82±2.08	**<0.01[a]**
	90° Flexion	88.01±19.96	90.50±2.20	**0.187[b]**
	120° Flexion	103.70±41.32	119.54±2.21	**0.152[b]**
	30° Abduction	39.07±5.31	32.83±2.52	**<0.01[a]**
	60° Abduction	64.30±5.21	61.46±2.26	**0.02[a]**
	90° Abduction	89.37±14.28	90.33±1.62	**0.137[a]**
	120° Abduction	93.55±50.67	119.27±1.72	**0.51[b]**
	15° Internal rotation	21.64±3.36	16.24±1.36	**<0.01[a]**
	30° Internal rotation	36.39±2.99	31.61±1.37	**<0.01[b]**
	45° Internal rotation	48.61±2.95	45.53±1.17	**<0.01[b]**
	15° External rotation	21.31±2.54	16.73±1.70	**<0.01[b]**
	30° External rotation	35.97±3.12	31.66±1.35	**<0.01[a]**
	45° External rotation	47.86±2.93	45.43±0.80	**<0.01[a]**
Muscle strength (N)	*Flexion*	5.5±1.4	6.4±1.3	**<0.01[a]**
	Hyper-extension	4.8±1.3	5.6±1.3	**<0.01[a]**
	Abduction	5.3±1.4	6.2±1.2	**<0.01[a]**
	Horizontal abduction	5.5±1.5	6.6±1.7	**<0.01[a]**
	Horizontal adduction	4.2±1.2	5.2±1.4	**<0.01[b]**
	Internal rotation	4.8±1.1	5.6±1.3	**<0.01[a]**
	External rotation	4.8±1.1	5.7±1.1	**<0.01[a]**

[a]paired sample t test, [b]wilcoxon t test, Mean±SD: Mean ± Standard deviation, °:Degree, N: Newton

Table 4 presents the study's examination of the relationship between the painful side's proprioception and muscle strength. A weak negative correlation was found between 30° flexion proprioception and muscle strength in flexion (-0.355) and abduction (-0.348) (p = 0.017, 0.019). Similarly, a weak negative correlation was observed between 30° abduction proprioception and muscle strength in hyperextension (-0.489), abduction (-0.396), horizontal abduction (-0.326), and internal rotation (-0.308) (p < 0.001, 0.007, 0.029, 0.039, respectively). A weak positive correlation was also noted between 120° abduction proprioception and abduction muscle strength (0.313) (p = 0.036). A weak negative correlation was identified between 15° internal rotation proprioception and muscle strength in flexion (-0.365) and abduction (-0.314) (p = 0.014, 0.036). Lastly, a weak negative correlation was found between 30° external rotation proprioception and horizontal adduction muscle strength (-0.327) (p = 0.028) (Table 4).

Table 3. Examining the relationship between non-painful shoulder's proprioception and muscle strength

Variables			Muscle strength (N)						
			FLX	EX	ABD	H-ABD	H-ADD	IR	ER
Proprioception (°)	30° FLX	r	-0.449[b]	-0.386[b]	-0.215	-0.180	-0.202	-0.142	-0.156
		p	0.002	0.009	0.156	0.238	0.183	0.353	0.305
	60° FLX	r	-0.196	0.103	-0.122	-0.041	0.098	-0.159	0.001
		p	0.197	0.500	0.425	0.791	0.524	0.298	0.994
	90° FLX	r	0.033	0.121	0.141	0.025	0.067	0.195	-0.046
		p	0.831	0.430	0.355	0.872	0.662	0.200	0.765
	120° FLX	r	-0.212	-0.090	-0.084	-0.163	-0.146	-0.246	-0.140
		p	0.162	0.555	0.582	0.283	0.340	0.104	0.360
	30° ABD	r	-0.337[a]	-0.351[a]	-0.404[b]	-0.094	-0.168	-0.316[a]	-0.017
		p	0.024	0.018	0.006	0.540	0.271	0.035	0.911
	60° ABD	r	-0.307[a]	-0.103	-0.131	-0.264	-0.210	-0.355[a]	-0.251
		p	0.040	0.501	0.390	0.079	0.165	0.017	0.096
	90° ABD	r	0.015	0.095	0.240	0.268	-0.006	0.265	-0.168
		p	0.922	0.537	0.113	0.075	0.970	0.078	0.269
	120° ABD	r	0.053	0.223	0.176	0.005	0.002	0.062	-0.021
		p	0.731	0.141	0.248	0.973	0.989	0.688	0.892
	15° IR	r	-0.435[b]	-0.339[a]	-0.334[a]	-0.342[a]	-0.247	-0.457[b]	-0.168
		p	0.003	0.023	0.025	0.021	0.102	0.002	0.271
	30° IR	r	-0.477[b]	-0.207	-0.348[a]	-0.239	-0.411[b]	-0.382[b]	-0.268
		p	<0.001	0.172	0.019	0.114	0.005	0.010	0.075
	45° IR	r	-0.405[b]	-0.187	-0.079	-0.230	-0.159	-0.267	-0.111
		p	0.006	0.218	0.608	0.129	0.298	0.077	0.467
	15° ER	r	-0.631[b]	-0.433[b]	-0.444[b]	-0.373[a]	-0.509[b]	-0.498[b]	-0.307[a]
		p	<0.001	0.003	0.002	0.012	<0.001	<0.001	0.040
	30 ER	r	-0.534[b]	-0.251	-0.213	-0.195	-0.248	-0.327[a]	-0.288
		p	<0.001	0.096	0.160	0.198	0.100	0.028	0.055
	45° ER	r	-0.273	-0.055	0.008	0.004	-0.017	-0.005	0.012
		p	0.070	0.719	0.959	0.977	0.912	0.976	0.938

[a]paired sample t test, [b]wilcoxon t test, Nm- Newton-metre, FLX: flexion, ABD: abduction, H-ABD: horizontal abduction, H-ADD: horizontal adduction, IR: internal rotation, ER: external rotation, °:Degree, N: Newton.

Table 4. Examining the relationship between painful shoulder's proprioception and muscle strength

Variables			Muscle strength (N)						
			FLX	EX	ABD	H-ABD	H-ADD	IR	ER
Proprioception (°)	30° FLX	r	-0.355[a]	-0.320[a]	-0.348[a]	-0.160	-0.206	-0.189	-0.280
		p	0.017	0.032	0.019	0.292	0.175	0.214	0.063
	60° FLX	r	-0.259	-0.087	-0.091	-0.155	-0.223	-0.066	-0.217
		p	0.086	0.572	0.554	0.310	0.141	0.667	0.152
	90° FLX	r	-0.105	0.024	0.108	-0.099	0.051	-0.057	-0.027
		p	0.492	0.878	0.480	0.520	0.738	0.710	0.860
	120° FLX	r	-0.015	0.184	0.178	-0.019	0.013	0.023	0.033
		p	0.922	0.226	0.241	0.902	0.930	0.879	0.830
	30° ABD	r	-0.261	-0.489[b]	-0.396[b]	-0.326[a]	-0.213	-0.308[a]	-0.276
		p	0.084	<0.001	0.007	0.029	0.160	0.039	0.067
	60° ABD	r	-0.057	-0.138	-0.043	0.033	0.098	0.176	0.125
		p	0.710	0.366	0.780	0.831	0.522	0.247	0.415
	90° ABD	r	-0.058	-0.049	0.182	0.035	0.104	0.020	-0.073
		p	0.705	0.749	0.231	0.819	0.495	0.898	0.634
	120° ABD	r	0.194	0.292	0.313[a]	0.194	0.190	0.105	0.114
		p	0.202	0.051	0.036	0.203	0.212	0.493	0.457
	15° IR	r	-0.365[a]	-0.248	-0.314[a]	0.156	-0.051	0.059	0.102
		p	0.014	0.100	0.036	0.306	0.737	0.702	0.506
	30° IR	r	-0.278	0.013	-0.180	0.100	-0.140	-0.073	-0.025
		p	0.065	0.934	0.237	0.512	0.361	0.635	0.870
	45° IR	r	-0.234	-0.188	-0.118	0.161	-0.119	-0.013	-0.072
		p	0.122	0.216	0.441	0.291	0.438	0.934	0.640
	15° ER	r	-0.136	-0.224	-0.067	-0.006	-0.167	-0.014	-0.140
		p	0.373	0.138	0.662	0.966	0.274	0.926	0.358
	30 ER	r	-0.113	-0.072	-0.168	-0.187	**-0.327[a]**	-0.128	-0.154
		p	0.460	0.637	0.269	0.218	0.028	0.403	0.313
	45° ER	r	-0.076	-0.169	-0.078	-0.139	0.039	-0.142	-0.224
		p	0.619	0.266	0.609	0.361	0.797	0.351	0.140

[a]paired sample t test, [b]wilcoxon t test, Nm- Newton-metre, FLX: flexion, ABD: abduction, H-ABD: horizontal abduction, H-ADD: horizontal adduction, IR: internal rotation, ER: external rotation, °:Degree, N: Newton.

DISCUSSION

Our study aimed to examine the relationship between shoulder proprioception and muscle strength in individuals with shoulder impingement syndrome. We found that individuals with shoulder impingement syndrome had reduced proprioception and muscle strength on the affected side compared to the unaffected side. Furthermore, proprioception on the affected side was associated with greater strength in the muscles responsible for shoulder flexion and abduction.

The interplay of muscle strength, impingement syndrome, and pain was investigated in wheelchair rugby players, revealing that decreased muscle strength correlated with pain and dysfunction (23). Similarly, decreased activation of scapular muscles and weakness in shoulder internal rotators were observed in individuals with impingement syndrome (24). In this context, our findings indicated that muscle strength for shoulder flexion, abduction, hyperextension, horizontal abduction, adduction, internal rotation, and external rotation were all compromised on the painful side in shoulder impingement syndrome.

Literature suggests that lower proprioception in painful conditions is explained by the hypothesis that the degree of neural adaptation in the central nervous system, due to pain, is potentially affected by persistent peripheral nociceptor activity over time (25). Alfaya et al. investigated the link between proprioception, pain, and functional disability in shoulder impingement syndrome, finding a correlation between proprioception and the intensity of shoulder pain and disability (26). Consistent with these findings, our study revealed that proprioception was significantly impaired on the painful side at 30° and 60° of flexion and abduction, as well as at 15°, 30°, and 45° of internal and external rotation.

During voluntary muscle activation, proprioception is facilitated by muscle spindles, which are sensors that detect changes in muscle length and the rate of muscle elongation. Muscle spindles not only send sensory information but also receive efferent motor signals (gamma motoneurons) that modulate the sensitivity of the regulatory system during voluntary muscle contractions (27). It has been suggested that increased muscle strength may enhance proprioceptive acuity by heightening the sensitivity of muscle spindles and motor pathways (27,28).

Impingement syndrome, which affects the musculoskeletal system, is characterized by pain (1). Abnormal EMG activation patterns have been shown to impair muscle function due to painful conditions in the shoulder (28). The literature suggests that a diminished sense of proprioception in impingement syndrome is attributed to the presence of proprioceptive receptors, such as muscle spindles and Golgi tendon organs, within the muscle tissue (1,6,14,30).

Our study found links between shoulder muscle strength and proprioceptive acuity, with varying correlations observed on both the affected and unaffected sides. The association between proprioception and muscle strength was stronger on the unaffected side than on the affected side, with variations across different parameters. Significant correlations were found between proprioception and muscle strength on the painless side. These correlations were stronger between 15° and 30° of internal rotation and 15° of external rotation proprioception and shoulder muscle strength. The muscles that facilitate shoulder internal rotation are more selectively developed than those for external rotation (31). In contrast, during internal rotation of the shoulder joint, the external rotation muscles engage in centrifugal contraction, aiding the shoulder joint in more controlled and stable coordinated movement (14). Concurrently, the tension required for shoulder position sense peaks during rotation (31). Thus, effective proprioceptive input may activate muscle spindle receptors, enhancing muscle function. This study's observation of a stronger association between internal and external rotation positions and shoulder muscle strength on the painless side aligns with these findings.

Our study found a correlation between shoulder proprioception at 30° flexion and the strength of flexion and abduction muscles, noting that proprioceptive errors decrease as muscle strength increases. Similarly, shoulder proprioception at 30° abduction is linked to the strength of hyperextension, abduction, horizontal abduction, and internal rotation muscles, reinforcing the previous observation. These correlations are particularly strong between proprioception at 30° flexion and abduction and shoulder muscle strength.

Current literature suggests that proprioception declines with changes in muscle strength, affecting the Golgi tendon organ and motor sensitivity, thereby influencing the musculoskeletal system (26). Supporting this, Mognadam et al. observed significant improvement in proprioception following strength training that increased muscle strength (28). Our findings regarding the painful side align with existing literature.

It was also observed that as proprioception increased at 120° abduction on the painful side, abduction muscle strength decreased. When a joint approaches its limit of motion, tension develops in the muscles, capsuloligamentous structures, and skin. Muscle spindles within the muscle, activated by passive stretching, send nerve signals. An increase in muscle spindle activation may occur when muscles are stretched near the end of their range of motion (ROM), potentially leading to a higher total spindle discharge and enhanced position sense acuity at the end range. The glenohumeral joint experiences stretching at the end of shoulder abduction (31). Janwantanakul et al.'s study indicated that proprioception varies across the shoulder's ROM and decreases as tension increases at the extreme angles of rotation (31).

We believe that the shoulder joint is most tense at 120° abduction, suggesting that this angle may not be ideal for measuring shoulder proprioception. The reason proprioception was not lower at 90° and 120° of abduction and flexion, where impingement is most prevalent, could be because at higher degrees of motion, the shoulder joint may rely more on dynamic stabilizers rather than static proprioceptive inputs from joint receptors. This dynamic compensation could mask proprioceptive deficits. Furthermore, the central nervous system may enhance proprioceptive feedback in positions prone to instability or impingement to protect the joint. This protective mechanism could explain why proprioception does not appear significantly impaired, despite the higher risk of impingement.

Additionally, our results show correlations in both the healthy and painful shoulders. This might be because the healthy shoulder may exhibit a more linear or predictable relationship between proprioception and strength due to optimal neuromuscular function. In contrast, the painful shoulder might show weaker, non-linear, or inconsistent correlations due to pain, altered movement patterns, or neuromuscular impairments.

CONCLUSION

Shoulder impingement syndrome can impair shoulder proprioception and reduce muscle strength. In cases of shoulder impingement, proprioception is closely linked to the strength of shoulder flexion and abduction muscles. We recommend that rehabilitation for shoulder impingement syndrome incorporate exercises aimed at improving proprioception, with a particular focus on strengthening flexion and abduction muscles. Additionally, proprioceptive exercises targeting both the affected and unaffected sides may be beneficial for enhancing muscle strength. Further research is needed to explore these approaches in greater depth.

Ethics Committee Approval / Etik Komite Onayı

The approval for this study was obtained from Clinical Research Ethics Board of Ankara Yildirim Beyazit University (Approval number: 06-261, Date: 14.06.2023).

Conflict of Interest / Çıkar Çatışması

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Author Contributions / Yazar Katkıları

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REFERENCES

1. Du WY, Huang TS, Chiu YC, Mao SJ, Hung LW, Liu MF, et al. Single-session video and electromyography feedback in overhead athletes with scapular dyskinesis and impingement syndrome. *J Athl Train*. 2020;55(3):265-73.
2. Tooth C, Gofflot A, Schwartz C, Croisier JL, Beaudart C, Bruyère O, et al. Risk factors of overuse shoulder injuries in overhead athletes: a systematic review. *Sports Health*. 2020;12(5):478-87.
3. Kim JH, Kwon OY, Hwang UJ, Jung SH, Ahn SH, Kim HA. Comparison of the shoulder external rotator strength and asymmetry ratio between workers with and without shoulder impingement syndrome. *J Strength Cond Res*. 2021;35(12):3364-9.
4. Land H, Gordon S, Watt K. Isokinetic clinical assessment of rotator cuff strength in subacromial shoulder impingement. *Musculoskelet Sci Pract*. 2017;27:32-9.
5. Kolber MJ, Hanney WJ, Cheatham SW, Salamh PA, Masaracchio M, Liu X. Shoulder joint and muscle characteristics among weight-training participants with and without impingement syndrome. *J Strength Cond Res*. 2017;31(4):1024-32.
6. Walecka J, Lubiatowski P, Consigliere P, Atoun E, Levy O. Shoulder proprioception following reverse total shoulder arthroplasty. *Int Orthop*. 2020;44(12):2691-9.
7. Sahin E, Dilek B, Baydar M, Gundogdu M, Ergin B, Manisali M, et al. Shoulder proprioception in patients with subacromial impingement syndrome. *J Back Musculoskelet Rehabil*. 2017;30(4):857-62.
8. Ager AL, Borms D, Deschepper L, Dhooghe R, Dijkhuis J, Roy JS, et al. Proprioception: how is it affected by shoulder pain? A systematic review. *J Hand Ther*. 2020;33(4):507-16.
9. Holla JF, van der Leeden M, Peter WF, Roorda LD, van der Esch M, Lems WF, et al. Proprioception, laxity, muscle strength and activity limitations in early symptomatic knee osteoarthritis: results from the CHECK cohort. *J Rehabil Med*. 2012;44(10):862-8.
10. Alkhamis BA, Reddy RS, Alahmari KA, Alshahrani MS, Koura GM, Ali OI, et al. Balancing act: unraveling the link between muscle strength, proprioception, and stability in unilateral hip osteoarthritis. *PLOS ONE*. 2024;19(2):e0298625.
11. Gabriela V, Rafael G, Felipe M, Cláudia L. Effects of proprioceptive training on ankle muscle strength in fencers: a clinical trial. *J Bodyw Mov Ther*. 2021;27:141-7.
12. Gumina S, Camerota F, Celletti C, Venditto T, Candela V. The effects of rotator cuff tear on shoulder proprioception. *Int Orthop*. 2019;43(1):229-35.
13. Echalier C, Uhring J, Ritter J, Rey PB, Jardin E, Rochet S, et al. Variability of shoulder girdle proprioception in 44 healthy volunteers. *Orthop Traumatol Surg Res*. 2019;105(5):825-9.
14. Shang XD, Zhang EM, Chen ZL, Zhang L, Qian JH. Correlation analysis of national elite Chinese male table tennis players' shoulder proprioception and muscle strength. *World J Clin Cases*. 2022;10(24):8514-24.
15. Iida N, Kaneko F, Aoki N, Shibata E. The effect of fatigued internal rotator and external rotator muscles of the shoulder on the shoulder position sense. *J Electromyogr Kinesiol*. 2014;24(1):72-7.
16. Reddy RS, Alshahrani MS, ALMohiza MA, Alkhamis BA, Tedla JS, Kakaraparthi VN, et al. Shoulder muscle weakness and proprioceptive impairments in type 2 diabetes mellitus: exploring correlations for improved clinical management. *PeerJ*. 2024;12:e17630.
17. Turgut E, Duzgun I, Baltaci G. Effects of scapular stabilization exercise training on scapular kinematics, disability, and pain in subacromial impingement: a randomized controlled trial. *Arch Phys Med Rehabil*. 2017;98(10):1915-23.
18. Abdullah MÜ, Sabriye E, Ahsen O, Cem Ç. Eklem Pozisyon Hissini Ölçmek İçin Akıllı Telefon Uygulamaları Kullanılabilir mi? *Turk J Sports Med*. 2017;52(1):4.
19. Yarin A, Saravia S, Coveñas L, Esenarro V, Tafur A. Confiabilidad test-retest de goniometría estándar y G-pro smartphone en el movimiento flexo-extensión del hombro [Test-retest reliability of standard goniometry and the G-pro smartphone in shoulder flexion-extension]. *Rehabilitacion (Madr)*. 2021;55(3):183-9.
20. Cildan Uysal S, Tonak HA, Kitis A. Validity, reliability and test-retest study of grip strength measurement in two positions with two dynamometers: Jamar® Plus and K-Force® Grip. *Hand Surg Rehabil*. 2022;41(3):305-10.
21. Saadet OA, Nezire K. Tedavi Hareketlerinde Temel Değerlendirme Prensipleri. 9th ed. Ankara: Hipokrat Kitapevi; 2016. p.163-9.
22. Cohen J. The analysis of variance. In Statistical Power Analysis for the Behavioral Sciences (second ed.). Lawrence Erlbaum Associates. 1988, 274-87
23. Moraes GF, Faria CD, Teixeira-Salmela LF. Scapular muscle recruitment patterns and isokinetic strength ratios of the shoulder rotator muscles in individuals with and without impingement syndrome. *J Shoulder Elbow Surg*. 2008;17(1 Suppl):48S-53S.
24. Miyahara M, Sleivert GG, Gerrard DF. The relationship of strength and muscle balance to shoulder pain and impingement syndrome in elite quadriplegic wheelchair rugby players. *Int J Sports Med.* 1998;19(3):210-4.
25. Kim S, Park J. Influence of severity and duration of anterior knee pain on quadriceps function and self-reported function. *J Athl Train*. 2022;57(8):771-9.
26. Alfaya FF, Reddy RS, Alkhamis BA, Kandakurti PK, Mukherjee D. Shoulder proprioception and its correlation with pain intensity and functional disability in individuals with subacromial impingement syndrome-a cross-sectional study. *Diagnostics (Basel)*. 2023;13(12):2099.
27. Salles JI, Velasques B, Cossich V, Nicoliche E, Ribeiro P, Amaral MV, et al. Strength training and shoulder proprioception. *J Athl Train*. 2015;50(3):277-80.
28. Nodehi-Moghadam A, Nasrin N, Kharazmi A, Eskandari Z. A comparative study on shoulder rotational strength, range of motion and proprioception between the throwing athletes and non-athletic persons. *Asian J Sports Med*. 2013;4(1):34-40.
29. Stackhouse SK, Sweitzer BA, McClure PW. The effect of experimental shoulder pain on contralateral muscle force and activation. *Physiother Theory Pract*. 2021;37(11):1227-34.
30. Chen Y, Yu Y, He CQ. [Correlations between joint proprioception, muscle strength, and functional ability in patients with knee osteoarthritis]. *Sichuan Da Xue Xue Bao Yi Xue Ban*. 2015;46(6):880-4.
31. Janwantanakul P, Magarey ME, Jones MA, Dansie BR. Variation in shoulder position sense at mid and extreme range of motion. *Arch Phys Med Rehabil*. 2001;82(6):840-4.