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Shoulder proprioception in patients with subacromial impingement syndrome

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Abstract.
BACKGROUND: Recently, proprioception deficits of the rotator cuff and the deltoid muscles have been suggested to play a pivotal role in the subacromial impingement syndrome (SIS). To date, there are no study has been found where the kinesthesia and joint position senses have been evaluated together in SIS.
OBJECTIVE: To investigate the shoulder proprioception in patients with SIS.
METHODS: Sixty-one patients with SIS and 30 healthy controls, aging between 25 and 65 years, were included in the study. Main outcome measure was proprioception, assessed with an isokinetic dynamometer. Kinesthesia, active and passive joint repositioning senses were tested at 0° and 10° external rotation. All tests were repeated 4 times and the mean of angular errors were obtained.
RESULTS: The mean age was 49.14 ± 10.27 and 48.80 ± 11.09 years in patient group and in control group respectively. No significant difference was found between two groups in terms of age, gender and dominance. When involved and uninvolved shoulders of the patient group were compared, kinesthesia, active and passive joint position senses were significantly impaired in involved shoulders at all angles ($P < 0.05$). When involved shoulders of the patient group were compared to the control group, kinesthesia, active and passive joint position senses were significantly impaired in involved shoulders in patient group at all angles ($P < 0.05$) except active position sense at 0°. When uninvolved shoulders of the patient group were compared to the control group, kinesthesia at 10° was significantly impaired ($P < 0.05$).
CONCLUSION: This study showed that shoulder proprioception was impaired in patients with SIS. This proprioceptive impairment was found not only in involved shoulders but also in uninvolved shoulders in patients with SIS.

Keywords: Shoulder, proprioception, kinesthesia, position sense, subacromial impingement syndrome

1. Introduction

Proprioception is a specialised sensory modality mediated by the articular, muscular and cutaneous peripheral receptors supplying input about the position and movement of the extremities. Conscious proprioception is necessary for all the daily and sportive activities and professional tasks. Unconscious proprioception plays a role in the modulation and coordination of muscle contraction and the reflex stabilization of the joints. For the position of the hand in the function of the upper extremity, the movement and position of the hand should be perceived at the shoulder level. The neural structures and mechanoreceptors in the capsule and ligaments of the shoulder joint send neurological feedback for the control of the shoulder muscle activity, and thus the position and movement of the joint is controlled and the reflex muscle contraction and joint stability is maintained. This leads to a protective effect against repetitive strains in the capsuloligamentous structures [1,2]. This neuromuscular control may become dysfunctional when the nervous reflex is

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Fig. 1. Patient's position in assessment of proprioception.

disrupted. An injury to muscular and articular structures and mechanoreceptors or painful disorders such as osteoarthritis [3] or hypermobility [4] impairs proprioception. This impaired proprioception and neuromuscular control may cause further injuries and further damage to the mechanoreceptors [5].

Clinically, the relationship between injuries and impaired proprioception have been widely studied in lower extremity pathologies [6–9]; and few studies have shown impaired proprioception in patients with shoulder injuries especially in patients with shoulder instability [10–16]. Although proprioceptive training and exercises following lower extremity injuries commonly recommended, there is little evidence of proprioceptive exercises after upper extremity injuries both shoulder instability [17] and rotator cuff problems [11,13]. It is also important to define the proprioceptive deficits in patients with SIS and this proprioceptive measurement can be used to follow-up the effects of proprioceptive training on proprioception in these patients. However, shoulder proprioceptive assessment is limited in patients with SIS. There are two studies investigating joint position sense in rotator cuff pathologies with conflicting results [11,16]. No study has been found where both kinesthesia and position senses have been evaluated together in SIS. A recent review stated that there is limited evidence about decreased reproduction of active repositioning (active joint position sense) acuity in patients with rotator cuff pathologies [18].

The aim of this study is to investigate shoulder proprioception, measured as kinesthesia and joint position sense (active and passive) in patients with SIS.

2. Methods

The study protocol was reviewed and approved by the Dokuz Eylul University Institutional Review Board and informed consent was obtained from all patients and controls. The study was conducted between May 2008 and August 2009. All the subjects signed a written informed consent before participating in the study. The demographic data from all the participants were recorded. The inclusion criteria were age between 25 and 65 and SIS diagnosed according to the magnetic resonance imaging (MRI-Zlatkin clasification) and physical examination. The SIS diagnosis during the physical examination was based on a positive Neer impingement sign and Hawkins test. The shoulder MRIs of the patients were examined by an experienced radiologist and the stages of the SIS were classified according to Zlatkin. According to this classification, Grade 1: Tendinitis-tendinosis; Grade 2: Degeneration in the tendon morphology (partial tear). Grade 3: A full-thickness tear [19].

The exclusion criteria included previous shoulder surgery and subacromial or intraarticular injections, bilateral shoulder disease, pregnancy, shoulder instability and joint hypermobility syndrome, diabetes, hypothyroidism, neurological and inflammatory joint diseases. Also, patients who had difficulty in adapting to the tests conditions were excluded from study. The patient group was enrolled from a previous study [13]. The control group consisted of patients without shoulder pain who had referred to our hospital. After the physical examination, proprioception was assessed both in the patients and the healthy controls. The proprioceptive measurement was based on kinesthesia and the joint position sense. The subject's elbow was flexed 90° and the shoulder was abducted 90°, while in the supine position on the isokinetic dynamometer test and treatment device (Cybex Norm, Ronkokoma, NC). In order to reduce visual and audial stimuli, the patient wore an eye mask and headphones. The shoulder and arm were placed in a pneumatic splint to reduce the sensory stimuli (Fig. 1). The preliminary research we conducted during the planning stage of our study has revealed that in our patients with the SIS, the severity of the pain was especially greater after the 30° external rotation and the evaluations were performed below this angle in order to maintain a certain standardisation. Kinesthesia was measured by establishing the threshold of detection of passive motion. Joint position sensibility, which is the perception of the joint position, was measured by the reproduction of passive position (RPP) and the reproduction of active position (RAP). These measurements were evaluated at 90° abduction and at 0° and 10° external rotation (ER) of the shoulder. For the kinesthetic sense, the device moved the shoulder and arm at a rate of 1°/sec from these starting

Table 1
Demographic characteristics of the groups

	Patient group ($n = 61$)	Control group ($n = 30$)	p values
Age (mean ± SD)	49.14 ± 10.27	48.80 ± 11.09	0.88
Gender (female/male)	42/19	21/9	1.00
Dominance (right/left)	58/3	30/0	0.54
Occupation (housewife/ working/leisured)	29/19/13	13/10/7	0.93

SD: standard deviation.

positions. When motion was first felt by the patient, the patient stopped the machine by pressing a handheld button. The angle the machine was stopped by the patient was recorded. The position sense was also assessed by finding the 10° target angles in the ER direction from the same starting positions. The device moved the arm from the starting position to a 10° angle in the ER direction by a rate of 5°/sec and held the arm at that position for 10 seconds in order for the patient to learn this target position. This procedure was reported three times. When the patient was accustomed with the angle to be learned, s/he was asked to push the handheld button and stop the device when s/he felt that the arm reached this angle as the device moved the arm to this angle passively. The error between the angle marked by the patient and the angle to be learned was measured and the RPP was assessed. Then, the patient was asked to find the learned angle by moving the device himself/herself, and by measuring the angular error, the RAP was determined. All the tests were repeated 4 times and the mean value of the angular errors was calculated.

2.1. Statistical analysis

The statistical evaluation was performed using the SPSS 15.0 (SPSS Inc., Chicago, IL) software. Data were analyzed using the Shapiro-Wilk test to establish the normality of the distribution. The normally distributed data were expressed in mean and SD. For the data outside the normal distribution, the median value was used as the measure of central tendency, with variability expressed as the interquartile range. For the inter-group comparisons, values within the normal distribution were assessed using the independent samples t-test, while the values outside the normal distribution were evaluated with the Mann–Whitney U-test. Categorical variables were compared through the Chi-square test. A value of $p < 0.05$ was accepted as statistically significant.

Table 2
Comparison of uninvolved and involved shoulder measurement of proprioception in patient group

Parameters	Uninvolved shoulder ($n = 30$)	Involved shoulder ($n = 61$)	p values
Kinesthesia ER0°	0.31 ± 0.44	0.80 ± 0.92	< 0.001*
Kinesthesia ER10°	0.77 ± 0.59	1.09 ± 0.78	0.03*
RPP ER0°	1.88 ± 0.99	2.89 ± 1.26	< 0.001*
RPP ER10°	2.01 ± 0.88	2.65 ± 1.77	< 0.001*
RAP ER0°	1.72 ± 0.82	2.13 ± 0.90	0.03*
RAP ER10°	1.73 ± 0.91	2.59 ± 0.89	< 0.001*

*$P < 0.05$, RPP: reproduction of passive position RAP: reproduction of active position ER: External rotation.

Table 3
Comparison of involved and control shoulder measurement of proprioception

Parameters	Involved shoulder ($n = 61$)	Control shoulder ($n = 30$)	p values
Kinesthesia ER0°	0.80 ± 0.92	0.21 ± 0.31	0.001*
Kinesthesia ER10°	1.09 ± 0.78	0.35 ± 0.35	< 0.001*
RPP ER0°	2.89 ± 1.26	1.98 0.98	0.001*
RPP ER10°	2.65 ± 1.77	1.87 0.80	0.002*
RAP ER0°	2.13 ± 0.90	1.86 0.73	0.15
RAP ER10°	2.59 ± 0.89	1.87 0.80	< 0.001*

*$P < 0.05$, RPP: reproduction of passive position RAP: reproduction of active position ER: External rotation.

Table 4
Comparison of uninvolved and control shoulder measurement of proprioception

Parameters	Uninvolved shoulder ($n = 61$)	Control shoulder ($n = 30$)	p values
Kinesthesia ER0°	0.31 ± 0.44	0.21 ± 0.31	0.25
Kinesthesia ER10°	0.77 ± 0.59	0.35 ± 0.35	< 0.001*
RPP ER0°	1.88 ± 0.99	1.98 ± 0.98	0.65
RPP ER10°	2.01 ± 0.88	1.87 ± 0.80	0.51
RAP ER0°	1.72 ± 0.82	1.86 ± 0.73	0.41
RAP ER10°	1.73 ± 0.91	1.87 ± 0.80	0.47

*P <0.05, RPP: reproduction of passive position RAP: reproduction of active position ER: External rotation.

3. Results

No significant difference was found between the two groups in terms of age, gender, occupation and dominance (Table 1). When involved and uninvolved shoulders of the patient group were compared, kinesthesia, RAP and RPP were significantly impaired in the involved shoulders at all angles ($P < 0.05$) (Table 2). When the involved shoulders of the patient group were compared to the control group, the kinesthesia and RAP and RPP were significantly impaired in the involved shoulders in the patient group at all angles (P

< 0.05) except for the active position sense at 0° (Table 3). When the uninvolved shoulders of the patient group were compared to the control group, kinesthesia was significantly impaired at 10° ($P < 0.05$) (Table 4). The patients' MRI grade according to Zlatkin Classification was found respectively grade 1; 31, grade 2; 17 and grade 3: 13.

4. Discussion

Proprioception is the afferent information regarding joint position sense, kinesthesia, and sensation of resistance. These three sub modalities are necessary features for a good neuromuscular control [20]. Our study is the first one showed that shoulder proprioception regarding kinaesthesia and RPP and RAP is impaired in SIS when compared to both controls and uninvolved side of the patients. This proprioceptive impairment is observed not only in the involved shoulders, but also in the uninvolved shoulders in the patients with SIS. Studies on proprioception in patients with rotator cuff tendinopathy are limited. There are only four studies investigating the proprioceptive acuity in patients with SIS [11,14–16]. Machner et al. showed impaired kinesthesia, defined as the perception of movement, in the affected side compared to the uninvolved side in patients with SIS who were treated by arthroscopic subacromial decompression. Before surgery, all patients had higher threshold levels for the perception of motion in their involved shoulders when compared to their uninvolved ones. After decompression, proprioception had improved on the decompressed side, but was unchanged on the uninvolved shoulder. But the patients were not compared to healthy controls [15]. Safran et al. have showed that kinesthesia is disturbed in 6 painful shoulders when compared to uninvolved side in the study that investigated shoulder proprioception in baseball pitchers. But sample size is too small and the diagnosis is not clear in this study [14]. Haik et al. evaluated joint position sense during medial and lateral rotations of the shoulder in female workers with and without SIS. There were no differences between sides for all groups and also no differences in any of the variables between the case group and the control groups [16]. But this study also has a small sample size and only joint position sense is assessed. A recent study demonstrated impaired shoulder joint position sense in patients with chronic rotator cuff pathologies. And the authors stated that their findings provide a theoretic rationale for proprioceptive rehabilitation programs in managing rotator cuff problems [11]. In a systematic review it has been reported that, there is moderate evidence showing an increase in the threshold to detection of passive motion in the uninvolved shoulder in comparison to the healthy controls in the patients with shoulder instability. Also in this review limited evidence was found for decreased RAP acuity for patients with chronic rotator cuff pain. Moreover, the authors of this review emphasized that these studies were conducted on small sample sizes and it is difficult to reach a definite conclusion [18]. We think our study has a valuable contribution in the literature about this subject. We found that both kinesthesia and joint position sense (RAP and RPP) were significantly impaired in the involved shoulders at all angles in patients with SIS. We have also observed that when the uninvolved shoulders of the patient group were compared to the control group, kinesthesia was significantly impaired at 10°.

Proprioception is considered to play an important role in the stabilization and coordination of the shoulder joint. Proprioception measurements were especially performed on the patients with labral tears or shoulder instabilities. Since the measurements are time consuming and the patients are get distracted, usually either kinesthesia or one of the position senses has been evaluated in these studies; studies where all three have been assessed are limited in number [21–24]. While assessment of kinesthesia does not give information about the position sense, evaluation of the position sense does not provide any evidence about kinesthesia. Therefore, it is recommended to evaluate both kinesthesia and the position sense. Although the measurements are time consuming, in our study, both kinesthesia and the active and passive repositioning sense were evaluated. Idin et al. found that the sense of joint position of uninvolved contralateral shoulders was impaired in patients with unstable shoulders. The uninvolved contralateral shoulders of patients who had been surgically treated also showed proprioceptive deficitis [25]. These results differ from some studies that reported a normal sense of joint position sense of the uninvolved shoulder [1,26]. Potz et al. observed a preoperative deficit in joint position sense of uninvolved contralateral shoulders that improved to normal postoperatively [27]. Similar findings of proprioceptive deficits of the contralateral joint were reported in patients with deficiencies of the anterior cruciate ligament, patellofemoral pain syndrome, meniscus [28–32]. We have observed impaired proprioception both in the involved and uninvolved sides com-

pared to the controls. The significant disturbance in the kinesthetic sense observed in the uninvolved shoulders of the patients may be explained with the intensive use of the uninvolved side in daily activities due to the pain on the other side. On the other hand; this phenomenon was attributed to the regulation of kinesthetic sense on a central level. Thus injury to one shoulder appears to influence the proprioceptive capability of the uninvolved shoulder.

In the studies focussing on proprioception in the upper extremities, no difference was observed in terms of the proprioceptive sense between the dominant and nondominant extremities [1,15]. In our study, the right shoulder was involved 37 patients (60.7%), while 58 patients (95.1%) were right-dominant. Therefore, the relationship between dominance and the involved side has not been investigated.

SIS occurs due to a mechanical disturbance within the subacromial space and is characterized by pain and functional restrictions mostly during overhead activities in daily life or sporting activities [33,34]. It is recommended to improve proprioception in order to continue the synergic contraction and normal function in the muscle groups in the shoulder and as a protection against repeated injury [11]. Studies have shown that the neuromuscular coordination may be improved through specific proprioceptive exercise programs [20,34–37]. Therefore, the assessment of proprioceptive deficits is important in SIS. Our study contributes to the literature by demonstrating that the joint position sense and kinesthesia are impaired both in SIS. Still, studies with larger sample size are required.

4.1. Study limitations

Proprioception was measured with various devices in the earlier studies, including custom-built devices, inclinometers, motion analysis systems and isokinetic dynamometry. Different starting positions (0° neutral, 40°–100° flexion, 90° abduction etc.) and target angles (10, 20, 75 degree external and internal rotation, neutral) were used in these studies. There is no standardized assessment of this procedure. Moreover, few studies make reference to the reliability of their testing procedures or equipment, an important consideration when assessing proprioception [38,39]. We assessed proprioception (kinesthesia and position senses) with isokinetic dynamometer system (CYBEX) in our study. The reliability of this procedure is shown by Aydın et al. [1] and is used in many other studies [16,40–42]. However, we did not study the reliability of our procedure. This may considered as a limitation of our study.

5. Conclusions

This study has demonstrated that patients with SIS have impaired shoulder proprioception. This proprioceptive impairment was found not only in the involved shoulders, but also in the uninvolved shoulders in patients with SIS. Proprioceptive impairment should be kept in mind and proprioceptive training should be added to the rehabilitation programs in the treatment of SIS.

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Conflict of interest

None to report.

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