International Orthopaedics
https://doi.org/10.1007/s00264-018-4150-1

ORIGINAL PAPER

The effects of rotator cuff tear on shoulder proprioception

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Received: 10 July 2018 / Accepted: 6 September 2018

Abstract

Purpose To evaluate the effects of rotator cuff tear (RCT) and its severity on shoulder proprioception.

Methods We studied 132 consecutive patients (67 M-65 F; mean age ± SD, 66.03 ± 9.04; range, 43–78) who underwent arthroscopic rotator cuff repair. Tear size was determined intra-operatively. The control group included 82 subjects (38 M-44 F; mean age ± SD, 65.87 ± 8.06; range, 41–75) with no RCT. All participants, wearing an eye mask, were submitted to the evaluation of the joint position sense (JPS) at 30°, 60°, 90°, 120°, and 150° of shoulder forward flexion during the sitting position, using a digital inclinometer securely attached to the subject's arm using hook-and-loop straps. The passive placement and active replacement method was used; the order of the tested angles was randomly selected. The entire test was repeated three times. The error score, by averaging the three trials, was measured as the absolute difference between the target angle and the observed angle. Statistics were performed.

Results The intraclass correlation coefficient for all degrees of flexion movement measured was > 0.90, exhibiting a very high correlation. We found significant differences between cases and controls regarding the results of joint position sense error at all measurements ($p < 0.05$). According to RCT size, we found significant differences between groups at 30° (F = 27.27, $p < 0.001$), 90° (F = 5.37, $p = 0.006$), 120° (F = 10.76, $p < 0.001$), and 150° (F = 30.93, $p < 0.001$) of shoulder flexion; in details, patients with massive RCT showed greater absolute error value than those with both small and large RCT at 30°, 90°, 120°, and 150° of shoulder flexion ($p < 0.05$).

Conclusions RCT provokes an alteration of shoulder proprioception, evaluated as the loss of joint position sense, and the impairment is related to tear severity.

Keywords Shoulder proprioception · Joint position sense · Rotator cuff tear and proprioception · Passive/active method for joint position sense · Massive rotator cuff tear and shoulder proprioception

Introduction

Rotator cuff tear (RCT) is a common musculoskeletal disorder: many studies demonstrated that RCT is present in nearly 30% of population aged 70 years [1–3]. Its aetiology is multifactorial with both intrinsic [4–7] and extrinsic [8, 9] factors causing tendon degeneration and damage.

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RCT is associated with pain, loss of strength, and impairment of range of motion leading to reduced quality of life [2, 10]. These aspects of rotator cuff disease are nowadays well described: recently, Gumina and colleagues [11] studied the intensity and distribution of shoulder pain, while the alterations in isometric and isokinetic muscle strength and the impairment in the activity of daily living in patients with RCT have been investigated by MacDermid et al. [12].

Expanding our knowledge, research is moving on the effects that this musculoskeletal disease causes on peripheral, spinal, and central neural factors, especially in the field of proprioception [13]. The latter is not a new concept; in 1906, Charles Sherrington coined this term considering it as "our perception of joint movement and positioning in space in the absence of visual feedback" [14]. During the years, this concept has evolved. Fortier and Basset [15] in 2012 conclude their research defining four domains: kinesthesia (joint

Published online: 14 September 2018

position sense and movement sense), sense of tension, sense of effort, and sense of balance.

Conscious proprioception is essential for professional tasks and for all daily and sports activities; on the other side, unconscious proprioception intervenes in coordination and modulation of muscle contractions and joints stabilization [16].

Alterations in proprioception caused by different musculoskeletal disorders have been studied in detail in lower extremity pathologies such as knee injuries [17], ankle sprains [18], and also in cervical [19] and lumbar spine disease [20].

Little information regarding impaired proprioception in shoulder injuries is known; the only studies are limited to shoulder instability [21, 22], idiopathic frozen shoulder [23], and subacromial impingement syndrome [24].

To date, the effect of RCT on shoulder proprioception remains unknown. To clarify this unresolved question, we assessed shoulder proprioception, through the evaluation of joint position sense, in a group of patients with different-sized RCTs, comparing the results with those of age-matched controls.

Material and methods

A case-control design study was performed. The cases consisted of 143 consecutive patients (70 M-735 F; mean age ± SD, 66.83 ± 9.74; range, 43–78) who underwent arthroscopic repair of a full-thickness RCT. Diagnosis of RCT was achieved by a physical examination, x-ray imaging (true anteroposterior and axillary view), and magnetic resonance imaging.

The control group was composed of 93 consecutive subjects (40 M-53 F; mean age ± SD, 65.16 ± 8.41; range, 41–75), enrolled in the outpatient clinic of our hospital. All these subjects were asymptomatic and had no history of shoulder pathologies; they were all submitted to a physical examination of both the anterior and posterosuperior rotator cuff tendons, performed by the more expert author (SG) in order to evaluate rotator cuff tendon status. If one or more tests were positive, subject was excluded from the control group since he could have an asymptomatic rotator cuff tear (n. 9). Finally, 84 subjects (38 M-44 F; mean age ± SD, 65.87 ± 8.06; range, 41–75) were enrolled as controls.

Exclusion criteria for all participants were the following: shoulder trauma; dorsal hyperkyphosis; shoulder flexion < 150°; primary osteoarthritis of the operated or contralateral shoulder; history of trauma of the shoulder; a previous operation on the shoulder; inflammatory joint disease; inflammatory, neurological (systemic or local), or infectious disease; cognitive or psychiatric disorders; and use of antidepressants, anxiolytics, or other medications that could have affected attentional and sensory processes.

All participants were submitted to the evaluation of the joint position sense (JPS) at 30°, 60°, 90°, 120°, and 150° of shoulder forward flexion, using a digital inclinometer securely attached to the subject's arm using hook-and-loop straps. The order of the tested angles was randomly selected.

All tests were performed with the subject in the sitting position with the thorax securely attached to the back of the chair, to avoid spine movements.

The examiner actively assisted the subject's arm to the target angle giving instructions to hold it there for three seconds before returning to the starting position (passive placement).

The subject wore an eyes mask to eliminate any visual cues and, while at the target angle, was told to concentrate on that position of the arm. Then, the arm was returned to the starting point, and the subject was instructed to return it back to the target angle (active replacement). When he/she had the feeling that the right position was achieved, the investigator recorded the angle on the inclinometer. The protocol was the same for all the different target angles. The entire test was repeated three times by the same assessor, with five minutes of interval time, to estimate intra-assessor reliability.

The error score, by averaging the three trials, was measured as the absolute difference between the target angle and the observed angle.

One of the authors (SG) performed all arthroscopic treatments. During surgery, the size of the lesion, previously assessed with the MRI, was confirmed intra-operatively according to the Southern California Orthopedic Institute (SCOI) classification [25] of complete rotator cuff tears. To limit the number of groups and make the sample more representative, we considered lesions belonging to type I as small, those of the type II and III as large, and those of the type IV as massive.

All participants signed an informed consent form in accordance with the Declaration of Helsinki. According to the law of our country, this study does not need any ethics committee approval.

Statistical analysis

Parametric tests were used if data were normally distributed and homogeneous. These assumptions were assessed by Kolmogorov–Smirnov's test and Shapiro–Wilk test, respectively. The normally distributed data were expressed in mean and SD.

The intraclass correlation coefficient [ICC (2,k)] was used to determine intra-assessor reliability. The ICC ranges from 0 to 1, with 1 indicating perfect reliability. ICCs were interpreted as follows: 0.00–0.25 = little, if any, correlation; 0.26–0.49 = low correlation; 0.50–0.69 = moderate correlation; 0.70–0.89 = high correlation; and 0.90–1 = very high correlation [26].

According to JPS at 30°, 60°, 90°, 120°, and 150° of forward shoulder flexion, the unpaired t test was performed to compare the two groups concerning the absolute error value.

According to RCT size, one-way ANOVA was used to evaluate the differences between three groups of JPS at 30°, 60°, 90°, 120°, and 150° of forward shoulder flexion considering the absolute error value. Significant levels for multiple comparisons were adjusted with the Bonferroni–Holm procedure.

The Statistical Package for Social Sciences (SPSS) ver. 20 (SPSS Inc., Chicago, IL, USA) was used for calculations. A single researcher analyzed all data. Computed p values were two-sided, and $p < 0.05$ was taken to indicate statistical significance.

Results

A total of 214 patients were enrolled. Table 1 shows baseline characteristics of the study group. Concerning intra-assessor reliability, the ICCs for all degrees of flexion movement measured were > 0.90, exhibiting a very high correlation.

Groups were homogenous and normally distributed at 30°, 60°, 90°, 120°, and 150° of shoulder flexion with regards the absolute error values.

Table 2 shows the results of JPS absolute error at 30°, 60°, 90°, 120°, and 150° of shoulder forward flexion. We found significant differences between cases and controls at all measurements ($p < 0.05$).

According to RCT size, we found significant differences between the groups at 30° ($F = 27.27$, $p < 0.001$), 90° ($F = 5.37$, $p = 0.006$), 120° ($F = 10.76$, $p < 0.001$), and 150° ($F = 30.93$, $p < 0.001$) of shoulder flexion; in details, patients with massive RCT showed greater absolute error value than those with both small and large RCT at 30°, 90°, 120°, and 150° of shoulder flexion ($p < 0.05$) (Fig. 1).

Table 1 Baseline characteristics of the two groups

	RCT (*N* = 132)	CG (*N* = 84)
Age (SD)	66.03 ± 9.04	65.87 ± 8.06
Gender (*N*)	65 Female	42 Female
	67 Male	38 Male
RCT (*N*)		VAS (SD)
- Small	43	6.39 (SD 1.71)
- Large	54	4.55 (SD 1.82)
- Massive	35	3.32 (SD 1.86)

SD, standard deviation; *RCT*, rotator cuff tear; *CG*, control group

Table 2 Joint position sense, according to the absolute error value, in cases and controls

Shoulder flexion (°)	Mean ± SD	CI 95% mean difference		*p* value
		Lower	Upper	
30°				< 0.001
- RCT group	8.9 ± 5.75	2.76	6.31	
- CG	4.35 ± 3.19	3.08	5.99	
60°				< 0.001
- RCT	12.26 ± 4.39	3.30	6.24	
- CG	7.48 ± 3.81	3.37	6.17	
90°				0.037
- RCT	14.27 ± 11.50	0.23	7.50	
- CG	10.40 ± 7.57	0.73	7.00	
120°				0.01
- RCT	12.87 ± 9.85	1.19	7.18	
- CG	8.68 ± 4.81	1.81	6.56	
150°				0.021
- RCT	10.04 ± 8.99	− 0.31	5.06	
- CG	7.65 ± 4.54	0.39	4.39	

SD, standard deviation; *RCT*, rotator cuff tear; *CG*, control group

Discussion

Proprioception is the product of sensory information supplied by specialized nerve endings termed mechanoreceptors, i.e., transducers converting mechanical stimuli to action potentials for transmission to the central nervous system (CNS) [27]. Mechanoreceptors specifically contributing to proprioception are termed proprioceptors and are found in muscle, tendon, joint, and fascia; receptors in the skin can also contribute to proprioception [27, 28].

The role of proprioception in sensorimotor control is multifold [29]. To plan appropriate motor commands, the CNS needs an updated body schema of the biomechanical and spatial properties of the body parts, mainly supplied by proprioceptors [30]. During movements, proprioception has importance for feedback (reactive) control, feedforward (preparatory) control, and the regulation of muscle stiffness, to achieve specific roles for movement acuity, joint stability, coordination, and balance [31, 32].

Many authors [26, 33–35] investigated location and function of proprioceptors in both human and animal shoulders; rotator cuff tendons and muscles were found to be associated with the highest concentration of proprioceptors, in particular of muscle spindles and Golgi tendon organs with glenohumeral joint and ligament receptors playing a minor role [36, 37].

Many studies investigated the changes in shoulder proprioception in patients with idiopathic frozen shoulder [23], suprascapular nerve neuropathy [38], anterior shoulder instability [21, 22], glenohumeral arthritis needing shoulder

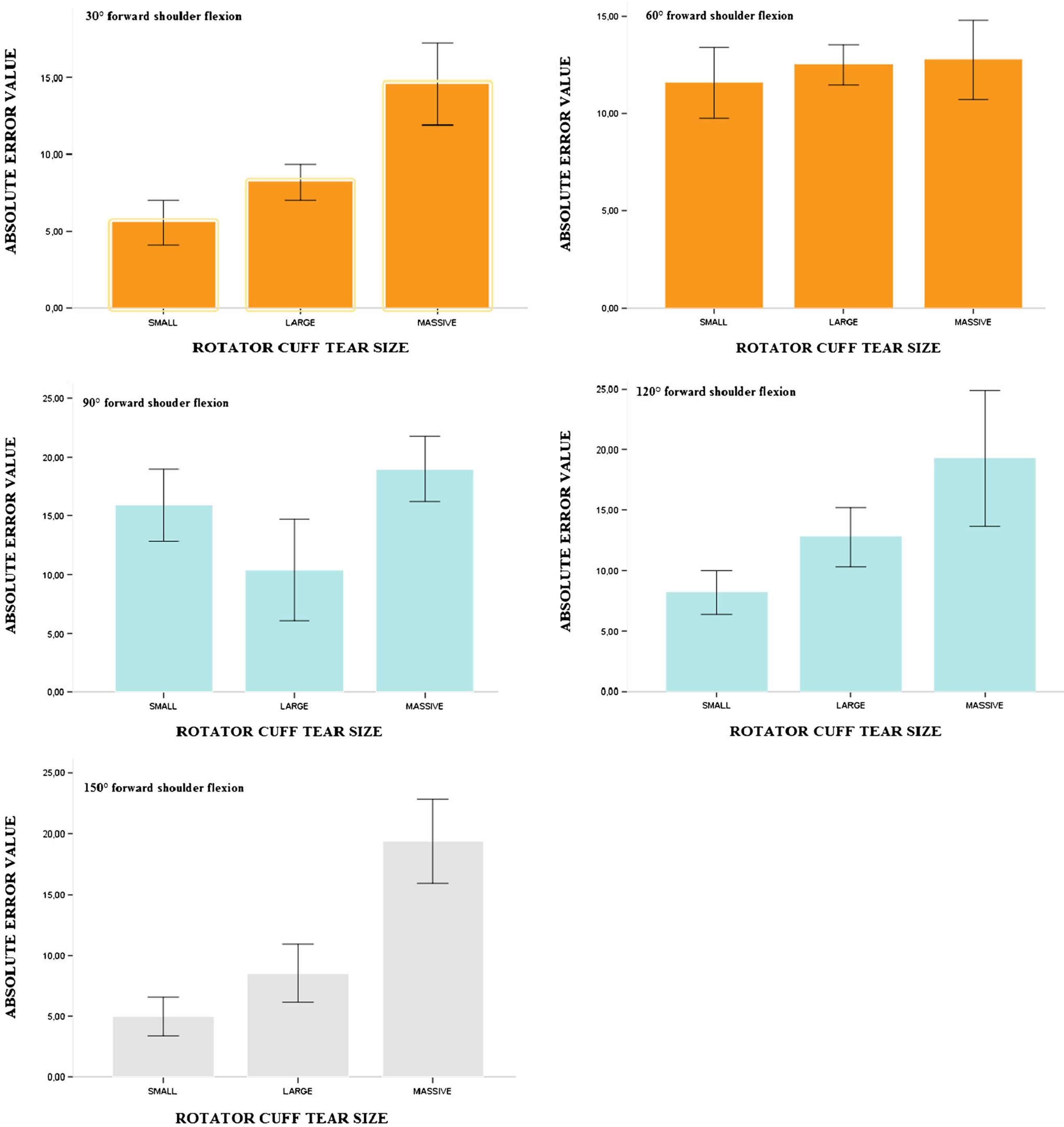

Fig. 1 Joint position sense, according to the absolute error value, in the group of patients with different-sized RCTs

replacement [39, 40], and after rotator cuff tear repair [41, 42]: impaired shoulder proprioception, at different level of severity, was found by all these authors.

Focusing on the subacromial space pathology, both Anderson et al. [43] and Maenhout et al. [44] investigated patients with rotator cuff pathology, founding a significant decrease in joint proprioception. Unfortunately, both the studied samples were composed of a small number of patients, and they do not include patients with RCT.

At our knowledge, it is the first study with the aim of assessing the effects on shoulder proprioception in a large cohort of patients with different-sized RCT compared with an age-matched control group and of analyzing if a correlation between tear severity and proprioception impairment existed.

Different methods have been used for the assessment of joint position sense [22, 43, 45–48]: the active/active, active-assisted, and passive/active protocols evaluating one or more between shoulder forward flexion, abduction, and internal and external rotation have been reported. Regarding the equipment used, proprioception has been investigated through isokinetic dynamometer [44, 49–51], inclinometer [51, 52], laser pointer [52], goniometer [52], continuous passive motion device [53], fabricated laboratory equipment [54–57], and motion analysis system [58, 59].

Based on both the lack of a standardized method and two recent studies [60, 61] in which the reliability of different protocols was measured, we evaluated joint position sense during the shoulder forward flexion using a passive/active protocol with a digital inclinometer. During the test, three seconds was used as the time needed for patients to identify the position; as previously described [15, 51, 62], it does not provoke the onset of fatigue during the testing session, not influencing our results.

Our study revealed a significant impairment of shoulder proprioception, assessed through the evaluation of the joint position sense, in patients with RCT compared with healthy subjects.

In rotator cuff complex, the largest concentration of muscle spindles and Golgi tendon organs has been demonstrated [37, 63]. According to recent thoughts, muscle spindles are considered the most critical proprioceptors, especially during movement [64]. Yellin et al. [65] evaluated proprioceptor activity of muscle spindles in tenotomized muscles in animal experiments; they found that tenotomy caused muscle shortening and changes in the surrounding extrafusal tissue leading to the modification of receptor activity level which became lower and distorted. Probably, these changes also occur in the human rotator cuff complex leading to the significant impairment of shoulder proprioception, registered in our group.

Regarding the size of RCT, we found that proprioception impairment was significantly higher in patients with more severe disease, for all the assessed target angles except for 60°. This finding might be explained by the fact that, according to the SCOI classification [25], cuff tears are defined as massive if two or more tendons are involved, and it implies a greater damage to the peripheral tissue and to its receptors; moreover, in this type of tear, an involvement of the glenohumeral joint is present with the consequent injury to the capsule proprioceptors, whose activity during shoulder movements has been documented [26, 36].

The alteration of the central processing of proprioceptive information could be another concomitant explanation. In fact, proprioceptive information is carried from the shoulder through the spinothalamic tracts to the somatosensory cortex, in a central body map, allowing the awareness of arm position and movement in space [66]. Massive tears are considered as chronic lesions, even if they could be asymptomatic for many years [1, 2, 67].

Considering the time elapsed from the onset of tendon injury, it is plausible that changes in brain activation patterns of shoulder proprioception may occur as documented in previous reports on patients with the history of recurrent shoulder instability [68], prolonged suprascapular nerve compression [69], and rotator cuff tendinosis/tendinitis [44].

Shoulder proprioception was not influenced by symptoms experienced by participants at the time of data collection, as differently reported by Anderson et al. [43] and Mörl et al. [47]. In fact, in our sample, impairment of shoulder proprioception was higher in patients with massive RCTs whose VAS values were found to be significantly lower to those of participants with less severe disease. Similar findings were reported by Sole et al. [50] who investigated the effect of experimentally induced subacromial pain on proprioception in a sample of healthy patients.

This study has limitations that need to be addressed. Among the submodalities of proprioception, only the joint position sense was investigated in our series. However, in practice, a single test is used to quantify proprioception and, considering our assessment method, the study methodology is reproducible, low-cost, leading to valid results.

Our study revealed that RCT provokes an alteration of shoulder proprioception, evaluated as the loss of joint position sense, and that this impairment is related to tear severity. The assessment of shoulder proprioception should always be performed during the physical examination of patients with RCT since it should be considered a sign of tear as well as pain, loss of strength, and alteration of the range of motion. Further studies will be needed to evaluate the recovery of proprioception after both tendon repair and specific rehabilitation protocol.

Compliance with ethical standards

All participants signed an informed consent form in accordance with the Declaration of Helsinki. According to the law of our country, this study does not need any ethics committee approval.

Conflict of interest The authors declare that there is no conflict of interest.

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