Research Report

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Comparison of Shoulder Total Rotational Range of Motion and External to Internal Rotation Strength Ratio between Assembly Line Workers with and without Subacromial Pain Syndrome

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Background Subacromial pain syndrome (SAPS) is one of the causes of shoulder pain in workers performing repetitive upper extremity movements. However, there have been no studies on physical characteristics such as shoulder total rotational range of motion (ROM) and external to internal rotation muscle strength ratio of workers.

Purpose The purpose of this study was to compare the total rotational ROM and external to internal rotation muscle strength ratio in workers with and without SAPS.

Study design A cross-sectional study

Methods This study included 35 workers with SAPS and 32 workers without SAPS. The total rotational ROM were measured using Smart KEMA motion sensor, and external to internal rotation muscle strength were measured using Smart KEMA pulling sensor.

Results The results showed that there were significant differences in the total rotation ROM between the groups ($p<0.05$). However, no significant difference was found in the external to internal rotation muscle strength ratio ($p>0.05$).

Conclusions Assembly line workers with SAPS had limited total rotational ROM. However, the ratio of external to internal rotation muscle strength ratio was not different for workers without SAPS. These characteristics can be considered factors that should be considered in evaluating workers with SAPS and establishing a treatment plan.

Key words External rotation; Internal rotation; Strength ratio; Subacromial pain syndrome; Total rotational range of motion.

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INTRODUCTION

Subacromial pain syndrome (SAPS) is common in workers performing repetitive arm movements.[1,2] The work processes that intensively use the upper extremities, including the shoulder joint, can be a risk factor for developing SAPS in workers.[1] SAPS refers to shoulder problems that cause localized pain around the acromion that often occurs during or after an arm lift motion.[3] The prevalence of SAPS has been reported to be 36–48% of all types of shoulder pain, and it has traditionally been thought that SAPS has a mechanical etiology where symptoms are induced by 'impinging' the subacromial structures due to a reduction in the subacromial space.[3–5] Diagnosis by clinical and/or radiological names such as bursitis, calcaneal tendinitis, supraspinatus tendinopathy, partial rotator cuff tear, biceps tendonitis or tendon degeneration are all considered part of the SAPS.[3]

The shoulder joint complex has six degrees of freedom and can perform movements in three axes.[6] Previous studies have shown that subjects with SAPS show a reduced range of motion (ROM) in shoulder joint motions.[2,7,8] McClure et al. reported that patients with SAPS had decreased ROM in all directions, including scaption, flexion, and shoulder external rotation (SER).[9] Warner et al. reported that patients with SAPS exhibited reduced ROM when performing shoulder internal rotation (SIR), which was attributed to the reactive fibrosis tissue of the capsule due to repetitive micro-trauma. Noonan said that a glenohumeral internal rotation deficit (GIRD) is associated with arm injuries in pitchers.[10] Also, Tyler et al. reported that patients with SAPS had decreased SIR ROM due to tightness of the posterior capsule, and patients with SAPS on the non-dominant side had decreased SER ROM due to less frequent use in activities of daily life.[2] However, they reported that there was no difference in the ROM of the external rotation when the patient had SAPS in the dominant side.[2] Wilk studied the correlation between total rotational motion, which is the sum of external and internal rotation ranges, and shoulder injuries, and reported that pitchers with a reduced total rotational range of 5 degrees or more had a higher risk of injury.[11]

Several studies have reported that weakness of the rotator cuff muscles is a contributing factor in the development of SAPS.[12,13] Sharkey and Marder observed that when the motion of the subscapularis, infraspinatus and teres minor muscles was weakened, abduction movement would cause the humeral head to move markedly superior according to the direction of action of the deltoid muscle.[13] Also, Mura et al. (2003) said that weakness of the infraspinatus muscle, one of the rotator cuff muscles, caused the superior motion of the humeral head.[12] Although the weakness of specific muscles can cause SAPS, other studies have reported conflicting results for strength in specific motions.[14,15] According to Erol et al., there was no difference in SIR strength between patients with and without SAPS, and no significant difference was found in SER strength between patients with and without SAPS.[14] Patients with SAPS reported only that the SIR strength on the involved side was relatively decreased compared to the strength on the normal side.[14] Also, Bak and Magnusson reported no significant difference in SER strength in elite swimmers with and without SAPS.[15] Many researchers have calculated the ratio of external to internal rotation muscle strength to identify imbalances that can lead to shoulder injuries such as SAPS.[16–21] According to the Ellenbecker and Davis, the external to internal rotator strength ratio is typically between 66 and 75%, and the external rotator muscle must exhibit at least two-thirds of the internal rotator strength to maintain muscle balance during shoulder motion.[20] Also, Saccol et al. reported that the ratio of external rotation and internal rotation isometric strength of the dominant arm and the non-dominant arm of male and female volleyball players was 64%–75%.[21] This ratio has been documented in several literature and is considered a predictor of shoulder injury.[18,19,22] So, the shoulder external to internal rotation strength ratio was considered as one of the factors to be measured when performing the evaluation of the upper extremity's function.[20] Clarsen et al. suggested that the change in the ratio of external rotation and internal rotation strength due to a decrease in external rotation strength could increase the risk of shoulder injury in handball players.[23] Similarly, it has been reported that the risk of shoulder injury due to changes in the external rotation and internal rotation ratio was similar in baseball pitchers.[24,25]

Although many studies have compared physical factors such as shoulder ROM, strength, and muscle strength ratio in patients with SAPS, most studies have included younger elite athletes. Frost and Andersen compared the shoulder function of workers with and without SAPS in a slaughterhouse or chemical factory, but in the study, simply using a constant score, the muscle strength was converted to 2 points per kilogram (kg) when performing flexion or abduction motions.[1] Additionally, Kim et al. compared the external rotation strength of workers with and without SAPS, but no study comparing the total rotational motion of external rotation and external to internal rotation strength ratio in workers with and without SAPS.[26] Therefore, this study aimed to identify any differences in total rotational ROM and muscle strength ratio of external to internal rotation between workers with and without SAPS.

METHODS

Subject

The design of this study was cross-sectional. 67 male assembly line workers (35 workers with SAPS and 32 workers without SAPS) participated in this study (Table 1). All subjects were explained about the risks and benefits associated with this study, and informed consent was signed.

Table 1. General characteristics of the subjects

	Workers with SAPS (n=35)	Workers without SAPS (n=32)
Age (yr)	46.3±7.2	44.8±8.0
Height (cm)	171.6±5.3	171.5±5.9
Weight (kg)	73.9±10.4	72.4±11.0
Body mass index	25.03±2.65	24.57±3.32

SAPS, subacromial pain syndrome.

The inclusion criteria for workers with SAPS were pain in the anterolateral side of the shoulder for more than 3 months and positive signs on orthopedic test (Neer sign and Hawkins test).[27] In this study, workers with SAPS were selected using the Neer and Hawkins test, a procedure for inducing symptoms related to subacromial pain syndrome.[27,28] The exclusion criteria were history of direct trauma to the shoulder; history of shoulder, elbow, or hand surgery; history of shoulder dislocation or subluxation; referred pain from neurologic or cardio-pulmonary disorders; acromioclavicular arthritis, infections, inflammatory or rheumatic diseases. This study was approved by the Yonsei University Mirae Institutional Review Board (approval number: 1041849-201710-BM-112-02).

Procedure

Before measurement, the workers performed a standardized warm-up, consisting of multiplane shoulder movements and were given instructions to become familiar with the measurement protocol and asked to practice shoulder ROM and strength measurements to perform appropriate movements. Then, the ROM and maximal isometric muscle strength of external and internal rotation of all workers were measured. To prevent muscle fatigue, the measurement protocol started with ROM measurements, and then the maximum isometric muscle strengths were measured. The order of internal rotation and external rotation measurements was randomized, and all measurements were repeated three times each. When measuring internal and external rotation strength, subjects maintained each measurement trial for 5 seconds and were given a 1-minute rest period between repetitions. To prevent muscle fatigue, a 5-minute rest period was given between internal rotation and external rotation strength measurements.

Instrumentation

Smart KEMA motion and pulling sensors (Smart KEMA system, KOREATECH Co., Ltd., Seoul, Korea) were used to measure ROM and strength. All shoulder ROM measurement data were expressed in degrees and shoulder muscle strength measurement data was expressed in kg. Muscle strength values were recorded in real time for 5 seconds and the average of the values in the middle 3 seconds was calculated via Smart KEMA software connected to the sensor for data analysis. The collected average muscle strength data were normalized to the subject's weight ([strength (kg) ÷ body weight (kg)] × 100). The total rotational ROM was calculated as the sum of external rotation and internal rotation ROM, and the external to internal rotation strength ratio was expressed as external rotation / internal rotation × 100.

Measurement of total rotational ROM

The ROM of the internal and external rotation joints was measured in the supine position of the subject. A strap equipped with a Smart KEMA motion sensor was fixed to the subject's wrist while the subject had the shoulder joint abducted 90 degrees and the elbow joint was flexed in 90 degrees. The sensor was calibrated in the starting position. The examiner held the subject's forearm and rotated the shoulder toward internal rotation and external rotation until the end feel of the shoulder joint was felt. To prevent anterior translation of the subject's humeral head, the examiner applied a constant posterior force to the subject's coracoid process and the clavicle with the palm of the hand (Figure 1).[29,30]

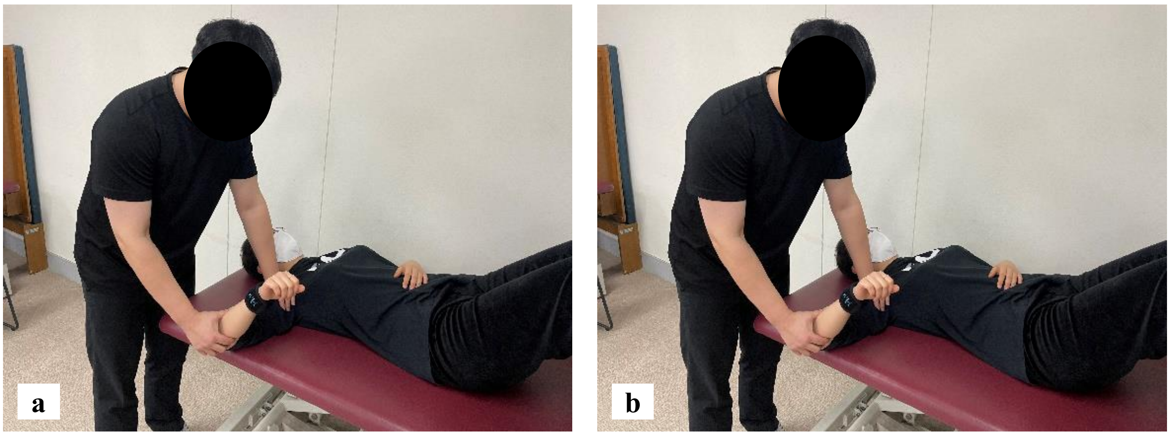

Figure 1. Measurement of total rotational range of motion: a) shoulder internal rotation; b) shoulder external rotation.

Measurement of rotation strength

The strength of the internal and external rotation joints was measured in the side-lying position of the subject. The internal rotation strength was measured in a position in which the subject maintained the shoulder in a neutral position and flexed the elbow by 90° with the arm for examination facing the table. The external rotation strength was measured in a position in which the subject was maintained with the shoulder and elbow flexed at 90° and the test arm was facing the ceiling. After attaching the strap with Smart KEMA tension sensor to the subject's wrist, it was placed at an angle of 90° to the direction of force and connected to the ground with a belt. The tension applied to the sensor before performing the measurement was maintained at 2 kg. Then, the subject's wrist was moved toward the ceiling to perform the motion with maximum force. The examiner held the subject's trunk by hand to prevent the subject's trunk rotation compensation movement during internal rotation measurement. Additionally, the examiner instructs the subject not to move the elbow of the tested arm away from the opposite palm to prevent a compensatory movement of shoulder abduction during external rotation measurement (Figure 2).

Statistical analysis

In this study, data were expressed as mean±standard deviation. All data were tested for normal distribution by using the Kolmogorov–Smirnov normality test. To compare the total rotational ROM and external to internal rotation strength ratio, between-group analysis (comparison between workers with and without SAPS) was performed using independent *t*-tests. All analyses were carried out using SPSS 25.0 (SPSS Inc., Chicago, IL, USA). The level of significance was set at 0.05.

RESULTS

Total rotational ROM was significantly different between assembly workers with and without SAPS (p=0.001) (Table 2). Workers with SAPS had significantly reduced total rotational ROM compared to workers without SAPS. The external to internal rotation strength ratio did not show a significant difference between workers with and without SAPS (p>0.05) (Table 3).

DISCUSSION

This is the first study conducted focusing on physical characteristics such as shoulder ROM and muscle strength in groups of workers with and without SAPS. This study aimed to compare the total rotation ROM and external to internal rotation strength ratio in workers with and without SAPS. We found that workers with SAPS had significantly reduced total rotational ROM compared to workers without SAPS.

Many studies have reported that a reduction in the range of motion of the shoulder internal rotation, called GIRD, affects shoulder stability and can lead to rotator cuff impingement and labial rupture.[2,31–33] Therefore, the assessment of GIRD and interventions are included when trying to prevent injury or to plan a rehabilitation program for athletes including tennis players and pitchers.[24,29,32] Wilk et al. considered that a GIRD greater than 20 degrees would be associated with the risk of injury in pitchers, but this correlation did not show a significant level.[11] However, a difference in total rotational ROM of more than 5 degrees was significantly associated with the risk of injury.[11] Wilk et al. considered that the risk of injury may be increased because the decrease in total rotational ROM associated with GIRD increases the demand for dynamic and static

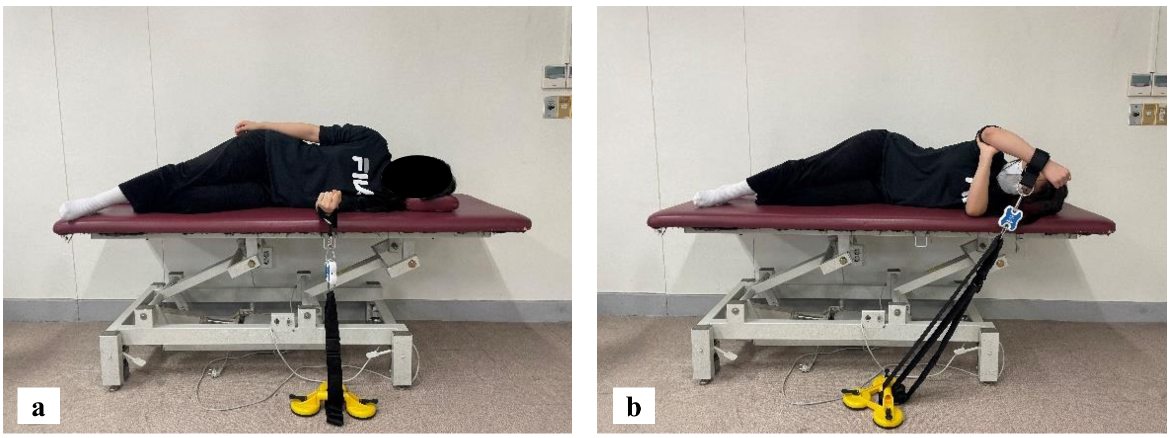

Figure 2. Measurement of rotator strength: a) shoulder internal rotation; b) shoulder external rotation.

Table 2. Comparison of total rotational ROM between workers with and without SAPS

	Workers with SAPS	Workers without SAPS	*t*	*p*
Total rotational ROM	140.27±15.14	155.98±19.31	3.72	0.001*

SAPS, subacromial pain syndrome; ROM, range of motion. * Significant difference between groups ($p<0.05$).

Table 3. Comparison of external to internal rotation muscle strength ratio between workers with and without SAPS

	Workers with SAPS	Workers without SAPS	*t*	*p*
External to internal rotation muscle strength ratio	79.12±40.21	74.43±21.90	–0.585	0.561

SAPS, subacromial pain syndrome.

stabilizers surrounding the shoulder joint.[11] The results of our study may also be attributed to the above reasons. In our study results, the total rotational ROM of workers with SAPS was 140.27°, and subjects without SAPS showed a total range of 155.98°, a difference of about 15 degrees. Considering that the difference in the total rotation ROM of the pitcher's dominant hand and the non-dominant hand in previous studies was about 2 to 4 degrees, and a difference of 5 degrees or more may have increased the risk of shoulder injury, the difference in total rotational ROM of workers with and without SAPS can be considered as clearly larger than the results of previous studies.[11,34]

Warner et al. found a decrease in the external to internal rotation strength ratio in a group of athletes with SAPS and suggested that this decrease could be due to a decrease in external rotational strength.[7] However, Bak and Magnusson reported swimmers with SAPS showed reduced internal rotation strength compared to the asymptomatic side, but no difference with respect to external rotation strength.[15] This resulted in a higher external to internal rotation strength ratio (83%), and the difference was significant compared with swimmers without SAPS (66%).[15] In our results, the mean external rotation to internal rotation strength ratio was slightly higher in workers with SAPS (79%) compared with subjects without SAPS (74%), but no significant difference was observed. According to Kim et al. (2021), the external rotation muscle strength of workers with SAPS was relatively decreased compared to the un-involved side, but compared with workers without SAPS, the external rotation strength itself did not decrease. Also, according to Erol et al., since it was measured in the pain-free range, there would be no significant difference in external rotation strength between patients with and without SIS.[14] They said that in the previous study, the age and gender of the subjects did not match, so there would be a difference in external rotation strength.[14] Additionally, compared to athletes who participate in competitions and improve their muscular strength to perform maximal performance, workers perform repetitive tasks, but need not to have a high level of strength that ordinary people cannot perform. For these reasons, our study results would not show a difference in the external to internal rotation strength ratio between workers with and without SAPS.

This study had several limitations as follows. First, this study was conducted on assembly workers with relatively high levels of physical activity during work. Therefore, it cannot be generalized to SAPS patients or office workers with relatively low levels of physical activity. The following study will need to compare the physical function of SAPS patients according to the level of physical use. Second, in this study, external and internal rotation strengths were measured as isometric contractions. In the following study, a comparative study through various types of contractions (concentric, eccentric) will be needed. Third, the results cannot be generalized to other shoulder disorders. Therefore, studies comparing the physical characteristics of workers with shoulder diseases other than SAPS that cause shoulder pain will be needed.

CONCLUSION

The conclusion of this study was that assembly line workers with SAPS had limited total rotational ROM. Nevertheless, the ratio of external to internal rotation strength did not differ compared to workers without SAPS. These characteristics can be considered factors to be considered understanding the physical differences between workers with and without SAPS, and when planning a rehabilitation program for assembly line workers with SAPS.

Key Points

Question Can the shoulder total rotational range of motion and external to internal rotation strength ratio be different between assembly workers with and without subacromial pain syndrome?

Findings The results of this study showed that workers with subacromial pain syndrome had a decrease in total rotation range of motion, but no difference in external to internal rotation strength ratio compared to workers without subacromial pain syndrome.

Meaning For shoulder rehabilitation of workers with subacromial pain syndrome, it may be helpful to consider the physical characteristics of reduced total rotational range of motion.

Article information

Conflict of Interest Disclosures: None.
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Ethic Approval: The present study approved by the Institutional Review Board of Yonsei University (Seoul, Korea) (approval no. 1041849-201710-BM-112-02). The study protocol was registered with the Clinical Research information Service (KCT0002678).

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