Muscle Activity Pattern of the Shoulder External Rotators Differs in Adduction and Abduction: an Analysis Using Positron Emission Tomography

VII. 4. Muscle Activity Pattern of the Shoulder External Rotators Differs in Adduction and Abduction: an Analysis Using Positron Emission Tomography

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To externally rotate the shoulder in abducted position is necessary for various activities of daily living, such as eating, shaking hands, combing, etc. The infraspinatus and teres minor are known to be the main external rotators of the shoulder. Although several authors investigated the difference in shoulder external rotation between abducted and adducted positions, the muscle activity pattern during shoulder external rotation has not been fully clarified. This study aimed to determine the activities involved in external rotation in adducted and abducted positions using positron emission tomography (PET).

Seven healthy volunteers without any history of shoulder pain or trauma were examined using PET in the present study. All participants were male and their dominant sides were right. Their average age was 33 years (range: 27-42). They underwent PET examinations after performing external rotation using an elastic band at both 0 degrees and 90 degrees of shoulder abduction in the frontal plane.

The FDG was dissolved in approximately 2 mL saline, which was then injected intravenously via the median cubital vein. The mean dose and the standard deviation of injected [^{18}F]fluoro-2-deoxyglucose (FDG) were 75.7 and 3.1 MBq, respectively. As for the external rotation exercise at 0 degrees of abduction, the exercise protocol consisted of repetitive shoulder external rotation in the supine position with the arm at the side. In each exercise, the shoulder was rotated from 30 degrees of internal rotation to 30 degrees of external rotation with a resistance using an elastic band (Thera-Band® Yellow, The Hygenic Corporation, Ohio, USA). The repetition number of exercise was 100 times before FDG injection and 200 times after the injection. PET images were collected 50 min after the

injection with a whole-body positron camera (SET-2400W; Shimadzu Inc., Kyoto, Japan). For each subject, PET scan was repeated two more times on separate days to obtain the data of external rotation exercise at 90 degrees of abduction as well as that of a resting condition (without any exercises).

Each PET image was fused to the corresponding MR image at the identical level using a software Dr. View/LINUX (AJS Inc., Tokyo, Japan) according to the methods reported in our previous paper by Omi et al.[1)], which enabled to delineate the contour of each shoulder muscle. Each PET image was fused to the corresponding MR image to identify each shoulder muscle. Subsequently, the volume of interest (VOI) was placed on the MR image for each shoulder muscle. Then, the standardized uptake values (SUVs) in each segment of the shoulder muscles were calculated to quantify their activities. Following this, we performed the following comparisons. First, the exercise/rest ratio of SUV was compared among five muscles both for 0 degrees and 90 degrees of abduction to clarify which muscle was most activated through the external rotation exercise. Second, TMi/ISP ratio of SUV (TMi: teres minor, ISP: infraspinatus) was established to determine the relative contribution of these two muscles to the external rotation exercise. Then, this ratio was compared at 0 degrees and 90 degrees of abduction.

A high FDG uptake was observed in all 4 rotator cuff muscles after external rotation exercise both in adduction and in abduction (Fig. 1). The infraspinatus showed the greatest muscle activity during external rotation at 0 degrees of abduction, whereas the teres minor showed the greatest activity at 90 degrees of abduction. The teres minor/infraspinatus ratio at 90 degrees of abduction (1.21±0.23; mean±standard deviation) was significantly higher than that at 0 degrees of abduction (0.84±0.15) ($P<0.01$).

The infraspinatus and teres minor are the main shoulder external rotators. The teres minor is more important as an external rotator in abduction than in adduction, as already published[2)].

References

1) Omi R, Sano H, Tashiro M, Itoi E, et al. *J Anat* **216** (2010) 643.
2) Kurokawa D, Sano H, Nagamoto H, Omi R, Shinozaki N, Watanuki S, Kishimoto KN, Yamamoto N, Hiraoka K, Tashiro M, Itoi E. *J Shoulder Elbow Surg* **23** (2014) 658.

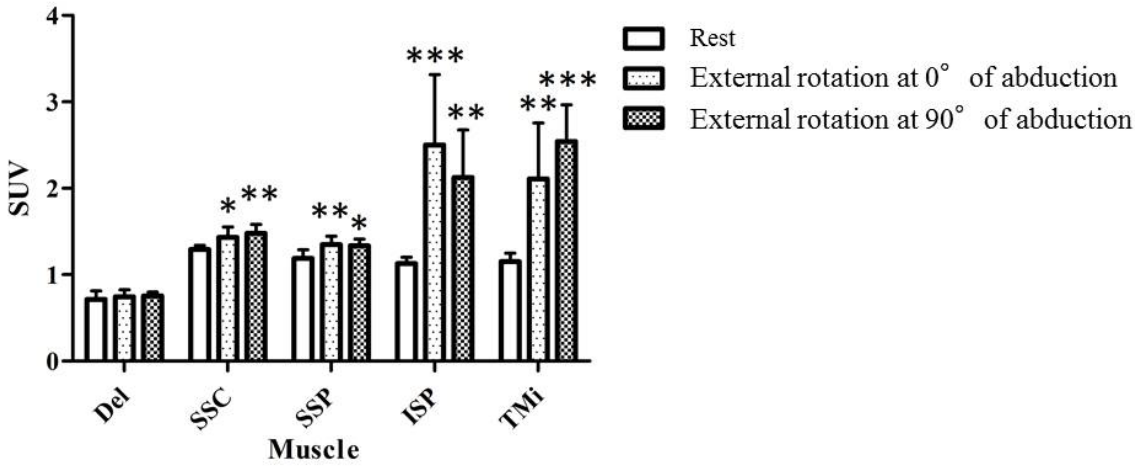

Figure 1. The mean standardized uptake value (SUV) for each shoulder girdle muscle.
Del: deltoid, SSC: subscapularis, SSP: supraspinatus, ISP: infraspinatus, TMi: teres minor. Statistically significant increase compared to at rest (*P<0.05, **P<0.01, ***P<0.001).