J Shoulder Elbow Surg (2015) 24, 955-964

ELSEVIER

JOURNAL OF SHOULDER AND ELBOW SURGERY

www.elsevier.com/locate/ymse

BASIC SCIENCE

# The effect of trunk rotation during shoulder exercises on the activity of the scapular muscle and scapular kinematics

**Taishi Yamauchi, PT[a,*], Satoshi Hasegawa, PT, PhD[a], Aoi Matsumura, PT, MSc[b], Masatoshi Nakamura, PT, PhD[a,c,d], Satoko Ibuki, PT[a], Noriaki Ichihashi, PT, PhD[a]**

[a]*Human Health Sciences, Graduate School of Medicine, Kyoto University, Kyoto, Japan*
[b]*Rehabilitation Unit, Kyoto University Hospital, Kyoto, Japan*
[c]*Japan Society for the Promotion of Science, Tokyo, Japan*
[d]*Faculty of Health and Sports Science, Doshisha University, Kyoto, Japan*

**Background:** In patients with shoulder disease, kinetic chain exercises including hip or trunk movement are recommended. However, the actual muscle activation and scapular kinematics of these exercises are not known. The purpose of this study was to examine the effect of trunk rotation on shoulder exercises that are devised to improve scapular function.
**Methods:** Thirteen healthy young men participated in this study. Scaption, external rotation in the first and second positions, and prone scapular retraction at 45°, 90°, and 145° of shoulder abduction were performed with and without trunk rotation. Electromyography was used to assess the scapular muscle activity of the upper trapezius (UT), middle trapezius (MT), lower trapezius (LT), and serratus anterior (SA), and electromagnetic motion capture was used to assess scapular motion. The muscle activity ratio, which is the activity of the UT to the MT, LT, and SA, was calculated. These data were compared between 2 conditions (with and without trunk rotation) for each exercise.
**Results:** Adding trunk rotation to scaption, the first external rotation, and the second external rotation significantly increased scapular external rotation and posterior tilt, and all 3 exercises increased LT activation. In addition, trunk rotation with scapular retraction at 90° and 145° of shoulder abduction significantly decreased the UT/LT ratio.
**Conclusions:** Our findings suggest that shoulder exercises with trunk rotation in this study may be effective in patients who have difficulty in enhancing LT activity and suppressing excessive activation of the UT or in cases in which a decreased scapular external rotation or posterior tilt is observed.
**Level of evidence:** Basic Science, Kinesiology.


**Keywords:** Shoulder exercise; kinetic chain; trunk rotation; rehabilitation; scapular kinematics; muscle activation ratio

This study has been approved by the Ethics Committee of the Kyoto University Graduate School and Faculty of Medicine: No. E1235.

*Reprint requests: Taishi Yamauchi, PT, Human Health Sciences, Graduate School of Medicine, Kyoto University, 53 Shogoin-Kawahara-cho, Sakyo-ku, Kyoto 606-8507, Japan.
E-mail address: yamauchi.taishi.83z@st.kyoto-u.ac.jp (T. Yamauchi).

1058-2746/$ - see front matter © 2015 Journal of Shoulder and Elbow Surgery Board of Trustees.
http://dx.doi.org/10.1016/j.jse.2014.10.010

Appropriate movement of the scapula is crucial for preventing shoulder injuries caused by accumulated minimal stress on the soft tissues surrounding the glenohumeral joint.[3-7,13,20-23,25,26,34] Inadequate scapular movements and positions are known to be a common cause of shoulder dysfunction or pain, and recovery of scapular control plays a key role in shoulder rehabilitation.[3,13,21,25,26,34] A previous review examining the scapular kinematics during shoulder elevation indicated that many studies found decreased upward rotation, posterior tilt, and increased internal rotation of the scapula during shoulder elevation.[26] Therefore, exercises in which the scapula moves into upward rotation, external rotation (ER), or posterior tilt are important.[24,32,33]

Proper scapular motion during arm elevation is achieved by force couples provided by the upper trapezius (UT), middle trapezius (MT), lower trapezius (LT), and serratus anterior (SA).[4-6,14,16,22,23,25,36] UT and SA act in scapular upward rotation, UT in scapular elevation, and SA in scapular protraction.[16] The MT and LT resist the SA during scapular protraction, and the LT resists the UT during scapular elevation; as a result, the MT and LT maintain the position of the scapula and build an axis of scapular upward rotation.[16] In addition, LT activity increases at ≥90° of arm elevation and is important for scapular posterior tilt.

A failure in cooperative activation of scapular muscles, including hyperactivity of the UT in combination with poor activity of the MT, LT, and SA, leads to inadequate scapular motion and shoulder pathologic changes.[4-6,25,36] Therefore, the relative activity of the UT with respect to the MT, LT, and SA (i.e., the muscle activation ratios of the UT/LT, UT/MT, and UT/SA) is of particular importance.[4,25,36]

Previous studies investigating the role of the scapula in shoulder disease have focused on scapular muscle activation during shoulder rehabilitation exercises; many have evaluated activation by electromyography (EMG).[4,22,23,33] However, scapular kinematics during such exercises are not well known. Oyama et al[33] investigated scapular kinematics and muscle activity during 6 scapular retraction exercises. They reported that scapular retraction with shoulder ER at 90° abduction and with shoulder ER at 45° abduction increased in scapular ER, upward rotation, and posterior tilt.[33] By knowing the scapular kinematics during exercises from these biomechanical studies, clinicians can obtain valuable information needed for selecting proper exercises for patients with shoulder disease.[33,35]

Recently, kinetic chain exercises including the hip and trunk extension or diagonal movement pattern in scapular retraction exercises are drawing attention because such exercises activate the scapular muscles, in particular the LT.[22,23,27] Nagai et al[32] examined the effect of trunk rotation added to shoulder flexion exercise in the sitting position and reported that scapular kinematics and muscle activity were changed with trunk rotation.

They reported that the ipsilaterally rotated trunk position during humeral elevation increased scapular ER and upward rotation, whereas a contralaterally rotated trunk position caused higher UT and SA activity and lower LT activity. In view of their research, shoulder exercises with ipsilateral trunk rotation may induce desirable scapular motion and muscle activation. However, to the best of our knowledge, no study has examined scapular movement along with the muscle activity and muscle activation ratio during various shoulder exercises with trunk rotation.

The aim of this study was to compare the scapular kinematics and muscle activity during various shoulder exercises with and without trunk rotation.

## Materials and methods

This is a cross-sectional basic science kinesiology study comparing scapular kinematics and muscle activity during various shoulder exercises with and without trunk rotation.

### Participants

Thirteen healthy young men (mean age, 21.5 ± 1.5 years; mean height, 172.5 ± 8.2 cm; and mean weight, 65.2 ± 7.4 kg) with no history of shoulder disease or any complaint participated in this study. All subjects were right-handed, and the dominant shoulder was tested. The study protocol was well explained, and all subjects fully consented to the study.

### Instrumentation

Three-dimensional kinematic data were obtained from the thorax, humerus, and scapula by use of an electromagnetic motion capture system (Liberty; Polhemus Inc., Colchester, VT, USA) operating at a sampling rate of 120 Hz. Its system electronics unit generates and senses the electromagnetic fields and computes the location and orientation of each sensor. A global coordinate system was established from a transmitter fixed on a board. Electromagnetic sensors were attached on the skin overlying the sternum, acromion, midpoint of the humerus (by a molded thermoplastic cuff), and styloid process of the ulna of the dominant arm. Next, to establish the anatomically based local coordinate systems (LCSs), the bone landmarks of the subjects were palpated and established by the Liberty sensor stylus with an embedded electromagnetic sensor while they stood with their arms hanging at the side. Each LCS was defined according to the recommendations of the International Society of Biomechanics.[37] The C7 spinous process, sternal notch, xiphoid process, and T8 spinous process were used to define the LCS of the thorax; the acromial angle, trigonum scapulae, and inferior angle were used to define the LCS of the scapula; the midpoint of the thermoplastic cuff on the humerus and the medial/lateral epicondyles were used to define the LCS of the humerus; and the medial/lateral epicondyles and ulnar styloid were used to define the LCS of the forearm. Previous studies have shown that 3-dimensional scapular kinematics can be assessed by this method with high accuracy in humeral elevation angles $<120°$.[18,29]

EMG activities were collected with a sampling rate of 1500 Hz by use of the TeleMyo DTS Telemetry system (Noraxon Inc., Scottsdale, AZ, USA). EMG activities and kinematic data