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Original Article

Relationship between scapular elevation exercises with different alignments and activity of the trapezius and levator scapulae muscles

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Abstract. [Purpose] This study aimed to examine whether scapular elevation exercises in sitting positions with different alignments lead to contractions of the trapezius and levator scapulae muscles. [Participants and Methods] The participants were 25 males, measured in four sitting positions with different alignments. Spine alignment was assessed by measuring the head protrusion, upper thoracic spine tilt, and pelvic tilt angles. Upper limb alignment was evaluated using the scapula tilt angle, scapula rotation angle, and distance between scapular spinous processes. Scapular elevation exercises were measured, and the thickness of the trapezius and levator scapulae muscles were measured in resting and elevated positions, with changes in muscle thickness. [Results] The trapezius muscle thickness was greater in the sitting position with less thoracic spine tilt and scapula tilt angles. Conversely, the levator scapulae muscle thickness was greater in the sitting position with more thoracic spine tilt and scapula tilt angles. [Conclusion] Scapular elevation exercises induce separate contractions of the trapezius and levator scapulae muscles by modifying the alignment of the spine and upper limbs.

Key words: Scapular elevation exercises, Spine and upper limbs alignment, Ttrapezius and levator scapulae muscle thickness

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INTRODUCTION

With the advancement of information and communication technology (ICT), the prevalence of musculoskeletal disorders among desk workers has been on the rise, emphasizing the need for disorder prevention measures[1)]. Among desk workers in Japan, neck pain has been reported as the most prevalent issue[2)]. This, in turn, leads to decreased labor productivity and the substantial financial losses of earnings among Japanese people[3)]. Chronic pain is particularly common in the neck and shoulders[4)], with tenderness often observed in the trapezius and levator scapulae muscles among individuals experiencing neck and shoulder pain[5)]. Recently, a medical intervention called ultrasound-guided hydro-dissection (hydro-release) has emerged as an effective treatment for neck pain and stiff shoulders[6)]. Hydro-dissection involves injecting saline solution between tissues by injection[7)]. Improving the gliding between fascia by injecting a saline solution between tissues to enhance symptom relief. The procedure aims to improve tissue gliding by creating a space between fascial layers, thereby providing potential therapeutic benefits. Stiff shoulders primarily involve the trapezius and levator scapulae muscles, and light exercises like scapular elevation exercises have been proposed to improve symptoms[8)]. However, it is presumed that scapular elevation

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exercises alone do not effectively enhance intermuscular gliding due to the simultaneous contraction of the trapezius and levator scapulae muscles. In clinical practice, it is often observed that these muscles contract separately during scapular elevation exercises when accompanied by changes in the spine and upper limb alignment. However, no previous studies have provided a detailed report on the specific conditions that lead to separate contractions of the trapezius and levator scapulae muscles. Clarifying these conditions would contribute to improved intermuscular gliding, alleviating neck pain and stiff shoulders while also preventing related disorders. Based on the above considerations, the purpose of this study is to investigate and identify the conditions that promote the individual activity of the trapezius and levator scapulae muscles.

PARTICIPANTS AND METHODS

This study was an observational cross-sectional study of healthy participants. The study enrolled a total of 25 healthy adult males with both right and left shoulders (mean ± standard deviation: age 23.3 ± 2.9 years, height 173.0 ± 5.2 cm, weight 66.8 ± 11.1 kg, BMI 22.3 ± 3.3 kg/m^2). Participants were recruited through oral communication and poster advertisements on campus at Bunkyo Gakuin University. To ensure the validity of the study results, individuals with a history of orthopedic diseases of the spine or upper extremities or previous surgeries were excluded. Prior to participation, all participants received written information about the study and provided informed consent by signing a consent form. This study was approved by the Ethical Review Committee of Tokyo Medical University (Approval No. T2020-0085) and Bunkyo Gakuin University (Approval No. 2022-3).

The measurement was conducted in a seated posture, where the participants sat on a chair with a seat height of 45 cm. Two sitting postures, namely an erect posture and a slouching posture, were defined based on a previous study[9]. In the erect posture (erect), participants were instructed to raise their pelvis, straighten their body, and face the front. In the slouching posture (slouching), they were instructed to round their body, assume a comfortable posture, and face the front. The upper limbs were positioned in two ways: drooped towards the body (drooping) and with the thumb held at the L5 spinous process (behind back), referencing previous studies[10, 11]. Four conditions were established based on the spine and upper limb alignment in the sitting posture: condition 1 (erect and drooping), condition 2 (erect and behind back), condition 3 (slouching and drooping), and condition 4 (slouching and behind back) (Fig. 1). These conditions were chosen to vary the position of the origin and insertion of the trapezius and levator scapulae muscles.

Measurements included the alignment of the spine and upper limbs, as well as the muscle thickness of the trapezius and levator scapulae muscles. Alignment measurements were performed using a digital level meter and a tape measure, following the methodology of a previous study[12]. Spine alignment was determined by measuring the head protrusion angle, (angle between the parallel line with the floor and the line connecting the C7 spinous process to the external auditory meatus), upper thoracic tilt angle (angle between the parallel line with the floor and the line connecting the C7 spinous process to the T5 spinous process), and pelvic tilt angle (angle between the parallel line with the floor and the line connecting anterior superior iliac spine (ASIS) to posterior superior iliac spine (PSIS)) according to previous studies[13]. Upper limb alignment included measurements of the right and left scapular tilt angle (angle between the perpendicular line to the floor and the line connecting the scapular spine to the inferior angle), right and left scapular rotation angle (angle between the parallel line to the floor and the line connecting the scapular spine to the acromion), and the distance between the right and left scapular spinous processes (distance between scapular spine and spinal column spinous processes) (Fig. 2).

Muscle thickness measurements were conducted using a digital ultrasound system HI VISION Preirus (Hitachi Medical Corporation, Tokyo, Japan) with a linear probe 18-5. The trapezius and levator scapulae muscles were measured on both sides at the midpoint of the line connecting the C1–C4 midpoints and the superior angle of the scapula, where the trapezius and levator scapulae muscles can be depicted, according to previous studies[14, 15]. The skin was marked at the midpoint, and the

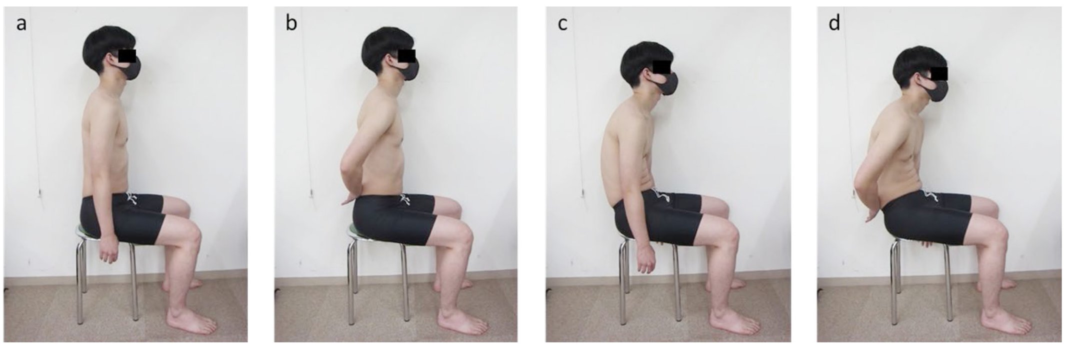

Fig. 1. Conditions of the spine and upper limbs in a sitting posture.
a: Condition 1 (erect and drooping), b: Condition 2 (erect and behind back), c: Condition 3 (slouching and drooping), d: Condition 4 (slouching and behind back).

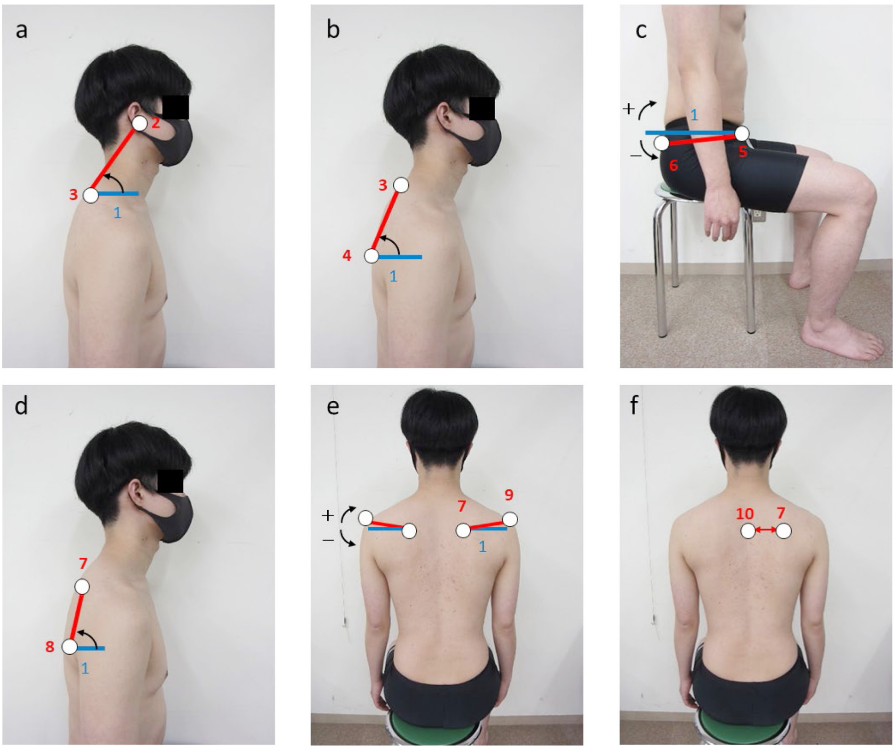

Fig. 2. Spine and Upper limbs alignment.
a: Head protrusion angle (spine alignment), b: Upper thoracic tilt angle (spine alignment), c: Pelvic tilt angle (spine alignment), d: Scapula tilt angle (upper limbs alignment), e: Scapula rotation angle (upper limbs alignment), f: Distance between scapula spinous processes (upper limbs alignment).
1: Line parallel to floor, 2: External acoustic aperture, 3: C7 spinous process, 4: T5 spinous process, 5: ASIS, 6: PSIS, 7: Triangle of spine of scapula, 8: Inferior angle of scapula, 9: acromion, 10: spinous process. ASIS: anterior superior iliac spine; PSIS: posterior superior iliac spine.

center of the probe was positioned precisely on the marked spot. Examiner A, who possessed expertise in using diagnostic ultrasound system, performed the probe manipulation, which relies on the operator's skill[16]. The measurement task involved a scapula raising exercise, as outlined in a previous study[14]. During this exercise, a 1 kg weight was wrapped around the upper arm, and the scapula was elevated by 3 cm. Hereinafter, this exercise is referred to as the "scapula elevation exercise". The height meter was set at a position where the measuring bar made contact with the acromioclavicular joint. The exercise was performed at a controlled speed of 3 cm in 3 seconds, guided by a metronome. The measurement protocol consisted of a resting position held for 3 seconds (resting position), followed by a slow and controlled scapular elevation movement over 3 seconds, and then maintaining the scapular elevation for an additional 3 seconds (elevated position).

To capture muscle thickness, ultrasound images were acquired with both the resting and elevated positions under the guidance of examiner B. Examiner A utilized the analysis software on the digital ultrasound system to measure the muscle thicknesses of the trapezius and levator scapulae muscles based on the acquired ultrasound images. The process of calculating muscle thickness data is depicted in Fig. 3. The percentage change (%) in muscle thickness for the trapezius and levator scapulae muscles were determined by dividing the thickness in the elevated position by the thickness in the resting position and then multiplying the result by 100. To ensure the reliability of the measurement method, the intraclass correlation coefficient (ICC) (1, 3) was calculated for alignment and muscle thickness in five additional participants (10 shoulders on each side) before the actual measurements. This was done by conducting three repeated measurements. The results demonstrated high repeatability, with ICC values of 0.9 or higher for alignment and 0.8 or higher for muscle thickness. All measurements were performed by examiner A to maintain consistency. Measurements were taken three times for each of the four conditions, and the average value was used for further analysis. Statistical analysis was performed using SPSS Statistics 28 (IBM, Tokyo, Japan). To assess the normality of the data, the Shapiro–Wilk test was employed. If the data followed a normal distribution, multiple comparisons using Tukey's test were conducted for variables that showed significance in the repeated measures analysis of variance. In cases where the data did not exhibit normal distribution, the Friedman test was utilized, and Bonferroni correction for multiple comparisons was performed using the Wilcoxon test for variables that showed significance. Spinal column alignment, upper limb alignment, and trapezius and levator scapulae muscle thickness were compared across the four conditions. The significance level was set at 5% for all four conditions.

RESULTS

The results of the normality tests indicated that the head protrusion angle, upper thoracic tilt angle, scapula tilt angle, and trapezius muscle thickness followed a normal distribution. On the other hand, the pelvic tilt angle, scapular rotation angle, the distance between scapular spinous processes, and levator scapulae muscle thickness did not exhibit a normal distribution. The results of spine alignment are shown in Table 1. The head protrusion angle, upper thoracic tilt angle, and pelvic tilt angle were significantly greater in conditions 1 and 2 compared to conditions 3 and 4 ($p<0.01$). Moreover, the upper thoracic tilt angle was significantly higher in condition 1 compared to condition 2 ($p<0.01$).

The results of upper limb alignment are shown in Table 2. The scapula tilt angle and scapular rotation angles were significantly greater in conditions 1 and 2 compared to conditions 3 and 4 ($p<0.01$). Furthermore, the scapula tilt angle was significantly higher in condition 1 than in condition 2 ($p<0.01$). Additionally, the distance between scapular spinous processes was significantly greater in conditions 3 and 4 compared to conditions 1 and 2 ($p<0.01$). Table 3 presents the results for the change in trapezius and levator scapulae muscles thickness. The trapezius muscle thickness change was significantly higher in condition 1 compared to conditions 2, 3, and 4 ($p<0.01$). On the other hand, the levator scapulae muscle thickness change was significantly higher in condition 2 compared to conditions 2, 3, and 4 ($p<0.01$). Additionally, in condition 3, the levator scapulae thickness change was significantly higher compared to condition 1 ($p<0.05$) and condition 4 ($p<0.01$).

DISCUSSION

This study aimed to investigate the impact of different spine and upper limb alignments activity on the activation of the trapezius and levator scapulae muscles during scapular elevation exercises. The findings suggest that specific conditions can enhance the activity of the trapezius and levator scapulae muscles. First, the alignment changes for each condition are summarized. In condition 1, the spine was maintained in an "erect" position, while the upper limbs were positioned in a "drooping" manner. In condition 2, the spine remained "erect", but the upper limb alignment was altered to a "behind back" position. This modification caused the scapula to tilt more anteriorly and led to increased kyphosis in the upper thoracic spine, compared to condition 1. In condition 3, the spine alignment was adjusted to a "slouching" position, while the upper

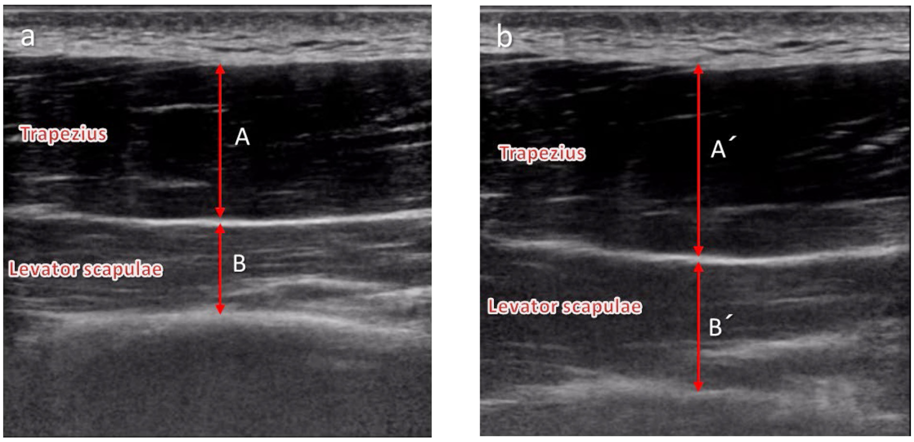

Fig. 3. How to calculate muscle thickness.
a: resting position, b: elevated position.
Trapezius muscle thickness change (%)= elevated position (A´) ÷ resting position (A) × 100.
Levator scapulae muscle thickness change (%)= elevated position (B´) ÷ resting position (B) × 100.

Table 1. Spine alignment for each condition

	Condition 1	Condition 2	Condition 3	Condition 4
Head protrusion angle (°)	$51.8 \pm 4.2^{**3, **4}$	$50.2 \pm 3.6^{**3, **4}$	39.5 ± 6.5	37.9 ± 5.9
Upper thoracic tilt angle (°)	$69.1 \pm 4.0^{**2, **3, **4}$	$64.3 \pm 3.8^{**3, **4}$	$52.7 \pm 5.3^{**4}$	49.1 ± 6.4
Pelvic tilt angle (°)	$0.5 \pm 2.7^{**3, **4}$	$-1.0 \pm 4.4^{**3, **4}$	-20.3 ± 9.4	-19.2 ± 12.8

^{**2}: $p<0.01$ (vs. Condition 2), ^{**3}: $p<0.01$ (vs. Condition 3), ^{**4}: $p<0.01$ (vs. Condition 4).
Condition 1: erect and drooping, Condition 2: erect and behind back, Condition 3: slouching and drooping, Condition 4: slouching and behind back.

Table 2. Upper limbs alignment for each condition

	Condition 1	Condition 2	Condition 3	Condition 4
Scapula tilt angle (°)	76.9 ± 5.6$^{**2, **3, **4}$	67.2 ± 5.1$^{**3, **4}$	60.8 ± 5.0^{**4}	56.6 ± 5.3
Scapula rotation angle (°)	−0.6 ± 4.1$^{**3, **4}$	−1.9 ± 3.4$^{**3, **4}$	−9.2 ± 4.7	−10.8 ± 3.9
Distance between scapula spinous processes (cm)	9.0 ± 1.1	9.1 ± 1.1	9.5 ± 1.0$^{**1, **2}$	9.4 ± 1.1$^{**1, **2}$

**1: p<0.01 (vs. Condition 1), **2: p<0.01 (vs. Condition 2), **3: p<0.01 (vs. Condition 3), **4: p<0.01 (vs. Condition 4).
Condition 1: erect and drooping, Condition 2: erect and behind back, Condition 3: slouching and drooping, Condition 4: slouching and behind back.

Table 3. Trapezius and levator scapulae muscles thickness for each condition

	Condition 1	Condition 2	Condition 3	Condition 4
Trapezius muscle thickness change (%)	130.5 ± 14.9$^{**2, *3, **4}$	121.6 ± 9.5	123.4 ± 9.7	121.1 ± 10.6
Levator scapulae muscle thickness change (%)	140.3 ± 16.3	169.9 ± 21.9$^{**1, **3, **4}$	154.6 ± 26.3$^{*1, **4}$	133.9 ± 20.2

**1: p<0.01 (vs. Condition 1), *1: p<0.05 (vs. Condition 1), **2: p<0.01 (vs. Condition 2), **3: p<0.01 (vs. Condition 3), *3: p<0.05 (vs. Condition 3), **4: p<0.01(vs. Condition 4).
Condition 1: erect and drooping, Condition 2: erect and behind back, Condition 3: slouching and drooping, Condition 4: slouching and behind back.

limbs were set to "drooping". Condition 4 involved a "slouching" spine alignment combined with an upper limb alignment of "behind back". These changes in the spine and upper limb alignment in conditions 3 and 4 resulted in kyphosis of the upper thoracic spine, posterior pelvic tilt, and a more forward head posture compared to conditions 1 and 2. Furthermore, alterations in the upper limb alignment led to an anterior tilt, downward rotation, and abduction of the scapula. Notably, condition 4 exhibited a more pronounced anterior tilt of the scapula compared to condition 3.

Next, the conditions under which the trapezius and levator scapulae muscles were more likely to contract are summarized. Condition 1 facilitated easier contraction of the trapezius muscles, while conditions 2 and 3 promoted greater elevation of the levator scapulae muscles. The differences in upper thoracic tilt angle and scapula tilt angle between conditions 1 and 2 played a significant role. The motion plane of the scapula is influenced by the shape of the thorax, as it rests on the thoracic cage[17]. In this study, the changes in the thoracic spine kyphosis and thoracic shape were considered to affect the direction of scapular motion. Specifically, condition 1 with a more upright thoracic spine and a less anterior tilt of the scapula facilitated a scapula elevation exercise in an upright direction, closely aligning with the origin and insertion of the trapezius muscle, thereby making the trapezius muscle contraction easier. Conversely, condition 2 with thoracic spine kyphosis and greater anterior tilt of the scapula resulted in an anterior upward scapula elevation exercise, approximating the origin and insertion of the levator scapular muscle, thus facilitating its contraction. The only notable difference between condition 3 and condition 4 was the angle of scapular forward tilt. In condition 3, the thoracic vertebrae were kyphotic, similar to condition 2, which facilitated the contraction of the levator scapular muscle. However, in condition 4, the thoracic spine displayed a more pronounced kyphosis, resulting in a greater anterior tilt of the scapula compared to condition 3. This positioning made it challenging for the levator scapular muscle to contract effectively. It is important to note that in the extended position of the muscles, static tension increases while active tension decreases[18]. Consequently, in conditions 3 and 4, where the scapula was in a state of downward rotation and abduction, and the trapezius muscle was in the extended position, the activity of the trapezius muscle was suppressed.

Insufficient gliding of the fascia between muscles and around peripheral nerves has been implicated in the development of pain[19]. Additionally, chronic pain has been associated with persistent hypertonia of muscles[20]. The trapezius and levator scapulae muscles, are known to be prone to persistent hypertonia[21], can contribute to intermuscular gliding dysfunction. In this study, our focus was on these specific muscles, which are associated with neck pain and shoulder stiffness. We examined scapular elevation exercises aimed at targeting these muscles individually. The findings suggest that "alignment of the thoracic spine", which influences the direction of scapular movement, and the "alignment of the scapula", where both muscles are attached, significantly impact the conditions that promote the activities of the trapezius and levator scapulae muscles individually. The alignment of the scapula was considered to be indirectly influenced by the alignment of the thoracic spine. Overall, the results of this study suggest that there is a spinal column and upper limb alignment that contracts the trapezius and levator scapulae muscles separately, leading to exercise therapy that promotes movement between the muscles.

In this study, the alignment of the spine and upper limbs was measured the measurement task. However, the study did not assess the alignment of the spine and upper limbs during the actual measurement task, nor did it confirm any changes in the alignment before and after the measurement task. This represents a limitation of this study. Additionally, the study did not measure the direction of movement during the scapular elevation exercise. To address this limitation, it is recommended to employ a three-dimensional motion analyzer to examine the changes in the spine and upper limb alignment throughout the entire measurement process, as well as to determine the specific direction of the scapular raising motion. Furthermore, muscle thickness was used as an index of muscle activity, but only a portion of the measurement task was verified. Therefore, it is important to verify changes in muscle activity over time using surface electromyography. Additionally, it would be beneficial to explore more detailed intermuscular movements by incorporating quantitative dynamic evaluations of muscles using ultrasound equipment[22].

Conflict of interest

The authors declare the there is no conflict of interests regarding the publication of this article.

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