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ORIGINAL RESEARCH

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Effectiveness of different bases of support during Y-raise exercises on upper and lower trapezius electromyographic activity in healthy male subjects

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Abstract

Background: Y-raise exercise (YE) is often recommended as an effective intervention for increasing lower trapezius (LT) muscle activation. **Methods**: 15 healthy males were asked to perform YE with different bases of support while lying prone: YE, YE on a Togu jumper (YET) and YE on a foam roller (YEF) in random order. Upper trapezius (UT) and LT activities were measured using surface electromyography during three different exercises. One-way repeated analysis of variance and Bonferroni *post hoc* test were used to compare the muscle activities. The significance level was set at $\alpha = 0.017$. **Results**: The muscle activity of LT and the ratio of LT/UT muscle activity were significantly different among three different exercises (YE, YET, YEF) (adjusted p-value (p_{adj}) $<$ 0.017). The muscle activity of LT was higher during the YEF than the YE and YET ($p_{adj} < 0.017$). The LT/UT muscle activity ratio during the YEF was higher than the YE ($p_{adj} < 0.017$). **Conclusions**: YEF can be recommended to selectively enhance LT activation and improve the LT/UT activity ratio in healthy male subjects.

Keywords

Base of support; Lower trapezius; Upper trapezius; Y-raise exercise

1. Introduction

Y-raise exercise (YE) is performed in the prone position by raising the arms above the head to achieve shoulder flexion [1]. While performing YE, patterns of scapular upward rotation and scapular posterior tilt are observed as part of the scapulohumeral rhythm [1–3]. This pattern is essential to achieve 180° of glenohumeral joint flexion, in which the scapula is slightly depressed and adducted [1, 4]. At the end range of scapular upward rotation, the scapula tilts posteriorly, in which the inferior angle of the scapula moves anteriorly and caudally and the coracoid process of the scapula moves posteriorly [1, 4, 5]. YE primarily targets the trapezius muscle, with the lower trapezius (LT) being the most activated during this exercise. A previous study reported that LT activation was 47.99% in the backward rocking arm lift position and 63.50% in the backward rocking diagonal arm lift position, suggesting that the latter is more efficient for LT activation [1]. Several previous studies have compared LT activation during YE at various shoulder abduction angles (180°, 160°, 125°, 90° and 75°), among which the greatest activation was reported at a shoulder abduction angle of 160°. This is because the direction of movement in YE aligns with the fiber direction of the LT [1, 6–9]. Thus, YE is an effective intervention for achieving LT activation.

The trapezius muscle controls head and neck movements at the vertebral joints and facilitates scapular motion at the scapulothoracic joint [10, 11]. It consists of the upper trapezius (UT), middle trapezius and LT fibers, which play important roles in stabilizing the shoulder joint and enabling functional movements [9, 12, 13]. During arm elevation, the UT, LT and serratus anterior (SA) muscles function as a force couple, generating coordinated forces to produce scapular upward rotation [1, 10, 14]. The UT plays an important role in the kinematics of the shoulder joint by performing upward rotation and elevation of the scapula [1, 9]. The LT extends the thoracic vertebrae and is important for scapular depression, upward rotation and stabilization of the scapulothoracic joint [1, 9, 15]. Along with the SA, the LT is involved in scapular posterior tilting, which helps widen the subacromial space and prevent impingement during arm elevation [1, 9]. A previous study compared trapezius muscle activation during different open kinetic chain exercises using a Thera-Band [16]. They revealed that LT activation was significantly higher than UT activation during shoulder external rotation exercises using a Thera-Band [16]. However, muscle imbalances between the UT and LT can lead to improper shoulder joint movements [9]. Excessive use of the UT can cause muscle shortness and increased muscle activation, resulting in muscle dominance [17, 18]. Furthermore, insufficient LT activation and weakness can cause improper scapular movement patterns, disrupt the scapulohumeral rhythm, and alter the length-tension relationships of surrounding shoulder muscles, leading to symptoms of shoulder impingement [9, 15, 16, 19]. This injury is commonly observed among physically active healthy adults, adults experiencing shoulder pain and athletes who perform overhead movements [20]. Therefore, it is essential to ensure proper balance between the UT and LT as well as muscle stabilization during shoulder exercises and functional activities such as arm reaching and lifting [1, 20, 21].

The base of support (BOS) is an important component of closed and open kinetic chain exercises [15, 22]. It refers to the area where a person/object comes in contact with the ground. For instance, while standing, the BOS includes the area occupied by the feet and crutches; in contrast, while sitting, the chair on which a person is sitting constitutes the BOS [15]. Adjusting the size and shape of the BOS can stimulate different somatic sensory experiences, affecting muscle onset time and muscle activation [1, 15, 23]. A systematic review reported that exercises focusing on treating scapular movement impairment or scapular dyskinesis should ideally start from a stable BOS and eventually progress to an unstable BOS [20]. This facilitates activation of the stabilizing muscles around the shoulder joint as well as activation of the trunk and leg muscles [23]. Additionally, joint stabilization exercises performed under weight-bearing conditions promote proprioception, leading to the activation of more muscles [24].

Using an unstable BOS requires controlling the center of mass, which stimulates proprioceptive joint receptors and increases the activation of distal muscles [21, 24]. Kim *et al.* [23] reported that exercises performed on an unstable BOS are more effective in reducing postural sway and improving balance ability than those performed on a stable BOS. In clinical settings, Togu jumpers and foam rollers are widely used as unstable BOS surfaces for performing rehabilitation exercises [23, 25]. The Togu jumper consists of a flat, hard plastic base and an air-filled pouch similar to a half-cut Swiss ball; it can be used on both sides [25]. Lee and Bae [26] compared the activation of UT and SA during the push-up plus exercise performed on a Togu jumper in three different positions (arms on Togu, legs on Togu and both arms and legs on Togu) [26]. They revealed that changes in SA activation were greater when both arms and legs were placed on the Togu jumper compared to the groups with only the arms on the Togu or only the legs on the Togu. Whereas UT activation was lower in this position than during push-up plus exercises performed with the arms on the Togu and legs on the Togu [26].

Furthermore, exercises using a foam roller provide continuous stimulation to the surrounding muscles, proprioceptive receptors and soft tissues while maintaining balance [27]. This also improves the ability to control muscle contraction intensity and neuromuscular coordination. A previous study focusing on lower limb and core exercises revealed that the use of foam roller considerably reduced the risk of injuries and falls by improving strength, endurance, balance, proprioception and coordination [27]. Another study examined the effects of a 4-week foam roller program versus a set of home exercises on rounded shoulder posture and UT muscle activity. In the foam roller group, the shoulder height from the table in the supine position decreased by 1.9 cm (from 7.30 to 5.40 cm) and UT activity decreased by 8.07 mV (from 105.95 to 97.88 mV) [28]. In contrast, the home exercise group showed the shoulder height from the table in the supine position decreased by 1.11 cm (from 6.78 to 5.67 cm), and an increase in UT activity of 6.36 mV (from 110.99 to 117.35 mV) [28]. Therefore, performing exercises with a foam roller is recommended to improve rounded shoulder posture and reduce excessive UT activation [28]. Gu *et al.* [29] examined UT and LT activation in female participants with rounded shoulders during scapular posterior tilt exercises in the prone position with different placements of the Togu. The exercises were performed under four surface conditions: floor, upper limb instability, lower limb instability and all four-limb (whole-body) instability [29]. The results showed that LT activation (74.36%) and LT/UT activation ratio (2.40) were higher under the four-limb instability condition than under the other three conditions [29]. Therefore, performing the exercise with whole-body on an unstable surface is an effective method for selectively improving LT activation and LT/UT activation ratio.

Based on these findings, the present study aimed to compare UT and LT activation and LT/UT activity ratio under three different YE conditions with variations in the contact area with the BOS: YE, YE on a Togu jumper (YET) and YE on a foam roller (YEF). The study hypothesized that YEF contributes to greater LT activation and higher LT/UT activity ratio compared with YE and YET.

2. Materials and methods

2.1 Participants

The sample size was calculated using G*Power (Version 3.1.2, Franz Faul, University of Kiel, Kiel, SH, Germany) with repeated measures analysis of variance (ANOVA). To achieve an effect size of 0.52 at a significance level of 0.05 and power of 80%, the sample size was calculated as 8. Accounting for a 10% dropout rate, the target sample size was set at 15. Accordingly, we recruited 15 healthy males in their 20s (mean age = 23.40 ± 1.96 years; height = 175.72 ± 3.56 cm; weight = 67.93 ± 5.09 kg; body mass index (BMI) = 22.01 ± 1.66 kg/m^2). This cross-sectional study was conducted from 20 August 2024 to 01 October 2024. Participants who showed negative results for the eccentric arm lowering test, shoulder flexion test, and shoulder internal rotation test were included [9]. In contrast, participants experiencing pain during shoulder joint movements within the past 6 months, those with a history of shoulder-related surgery within the past year, those unable to achieve full range of motion in shoulder flexion, or those with known neuromuscular or musculoskeletal disorders were excluded from the study [9, 15, 30]. The demographic characteristics of the study participants are presented in Fig. 1 and Table 1. Written consent was obtained from the participants. The study was approved by the Institutional Review Board of Hoseo University (1041231-240820-HR-184).

2.2 Electromyograph (EMG) and processing

2.2.1 Electromyography recording and data analysis

Muscle activation data were collected from the participant's dominant arm using surface EMG (Ultium EMG system, Noraxon Inc., Scottsdale, AZ, USA) [9, 31]. The EMG equip-

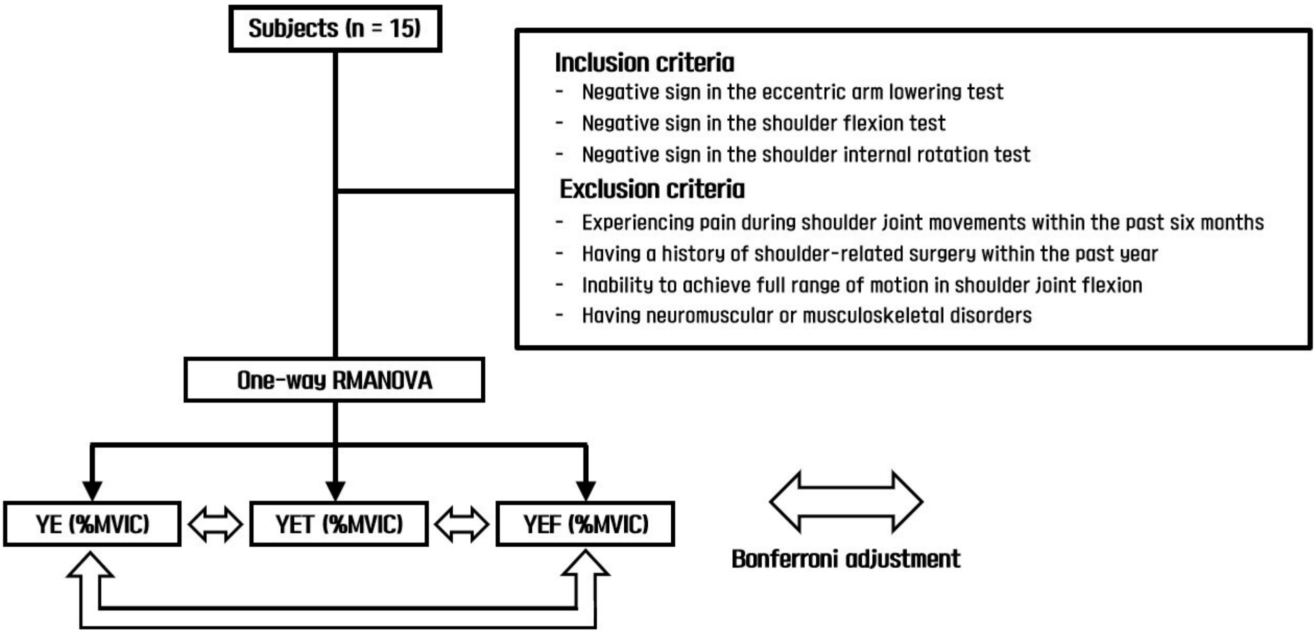

FIGURE 1. Flow chart. %MVIC, percentage maximal voluntary isometric contraction; YE, Y-raise exercise; YET, Y-raise exercise on togu jumper; YEF, Y-raise exercise on foam roller; RMANOVA, Repeated measured analysis of variance.

TABLE 1. General characteristics of the subject (n = 15).

	Mean ± SD
Age (yr)	23.40 ± 1.96
Height (cm)	175.72 ± 3.56
Weight (kg)	67.93 ± 5.09
BMI (kg/m^2)	22.01 ± 1.66

BMI, body mass index; SD, standard deviation.

ment settings were as follows: band-pass filter, 10–450 Hz; sampling rate, 1024 Hz and notch filter, 60 Hz. The collected data were processed using the root mean square method [9, 15]. Before attaching the electrodes, the attachment area was shaved and the skin was cleaned with an alcohol swab to minimize resistance; the cleaning process was repeated each time the sensors detached. Disposable silver/silver chloride surface electrodes (Ag/AgCl electrode) were then attached to the specified areas for UT and LT as per Criswell's guidelines. For the UT, the electrodes were placed at the point where the muscle mass between the C7 spinous process and the acromion was most prominent during contraction. For the LT, electrodes were placed on the oblique muscle, where the muscle mass was most prominent during contraction [9, 31].

To standardize muscle strength measurement, the maximum voluntary isometric contraction (%MVIC) test was conducted for the UT and LT. For the UT, the participant was allowed to sit with their neck turned to the side of the nondominant hand and asked to perform shoulder elevation and neck extension on the dominant side [9, 32]. The examiner provided resistance in a manner that caused the participant's head to flex anterolaterally while also providing resistance to lower their shoulder [9, 32]. For the LT %MVIC, the participant was asked to lie in the prone position, abducting their arm diagonally; they were then asked to lift the arm to tilt the scapula posteriorly [9, 32]. The examiner provided resistance by pushing the participant's arm downward in the extension direction [9, 32].

The examiner provided a detailed explanation of the exercise posture to ensure that the participants could perform the exercises correctly. Sufficient practice time was also provided until the participants became familiar with the YE posture. To minimize bias, each participant performed the three exercises in random order generated using a random number generator in Microsoft Excel (version 2024, Microsoft Corp., Redmond, WA, USA). Three trials of 5-s each were performed for the %MVIC measurement of each muscle, with a 1-minute rest between measurements to prevent fatigue [9]. The first and last 1 s of the signal were discarded [9, 31]. The surface EMG data were calculated and analyzed as the average of the three measurements. To minimize the effect of muscle fatigue while performing the three exercises, a 2-minute rest period was provided between exercises, and the participants were blinded to the effects and the purposes of the exercises [33].

2.2.2 Procedures

2.2.2.1 Y-raise exercise (YE)

After lying in the prone position on an adjustable table, the participants were instructed to abduct both arms to 160°. The height of the target bar was set to achieve 180° shoulder flexion when the arms were lifted [15]. The humerus was externally rotated to prevent the impingement, ensuring that the palms faced the ceiling [9, 15]. The maximal shoulder flexion at 180° was maintained for 5 s while the UT and LT activities were measured (Fig. 2A).

2.2.2.2 Y-raise exercise on Togu jumper (YET)

The participant was positioned prone on a Togu jumper with their sternum centered on the device. The remaining procedure was identical to YE (Fig. 2B).

2.2.2.3 Y-raise exercise on foam roller (YEF)

The participant was positioned prone on a foam roller (Moksha, Gyeonggi-do, Korea) with their sternum to pubic symphysis centered on the roller. The rest of the procedure was the same as YE (Fig. 2C).

2.3 Statistical analysis

All data were analyzed using Statistical Package for the Social Sciences ver. 20.0 (IBM Corp., Armonk, NY, USA, SPSS). The normal distribution of the data was confirmed using the Shapiro-Wilk test. One-way repeated measures ANOVA was used to compare the changes in muscle activation among the three different exercises, followed by Bonferroni adjustment for post hoc testing. The statistical significance was set at α = 0.017.

3. Results

3.1 Muscle activity

LT activation was significantly higher during YEF than during YE and YET ($p < 0.017$; Table 2, Fig. 3). LT activation during YET was significantly higher than that during YE ($p < 0.017$; Table 2, Fig. 3). However, there was no statistically significant difference in UT activation among the three exercise conditions ($p > 0.017$; Table 2, Fig. 3).

3.2 Muscle activity ratio

The LT/UT activity ratios during YET and YEF were significantly higher than those during YE ($p < 0.017$; Table 3, Fig. 3). However, there was no statistically significant difference in the LT/UT activity ratio between YET and YEF ($p > 0.017$; Table 3, Fig. 3).

4. Discussion

The present study compared UT and LT activation while performing YE using three different BOSs with varying contact areas. UT activation did not differ significantly among the three exercise conditions. However, compared with YE and YET, LT activation showed increases of 51.89% and 20.12% under YEF, respectively. YET resulted in a statistically significant increase (26.45%) in LT activation compared with YE. Similarly, compared with YE, the LT/UT activity ratio increased significantly under YET and YEF (26.89% and 45.63%, respectively). Although there was a 34.45% difference between YET and YEF, the difference was not statistically significant.

YEF showed a greater contribution to LT activation than YE and YET due to the unstable BOS. In other words, the YEF condition had the smallest contact area among the three exercise conditions. Hwang *et al.* [15] examined LT activation during shoulder flexion exercises with different BOS: shoulder flexion in a prone position (SFP), shoulder flexion in a push-up position with a Swiss ball (SFPUS), and shoulder flexion in a quadruped position with a Swiss ball (SFQPS). The results showed that LT activation increased progressively from SFP

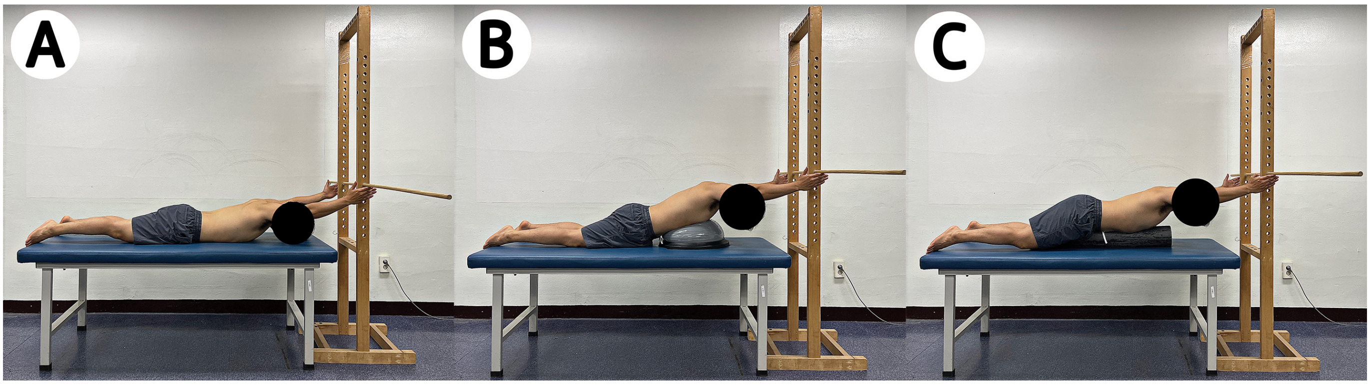

FIGURE 2. Three different Y-raise exercises. (A) Y-raise exercise; (B) Y-raise exercise on Togu jumper; (C) Y-raise exercise on foam roller.

TABLE 2. UT, LT muscle activities according to three different Y-raise exercises (n = 15).

%MVIC	Conditions			F	p
	YE	YET	YEF		
UT	50.50 ± 9.62	45.42 ± 6.86	41.87 ± 9.01	2.15	0.156
LT	41.63 ± 8.61	52.64 ± 9.80	63.23 ± 6.83	27.94	<0.001*

Mean ± standard deviation.
*%MVIC, percentage maximal voluntary isometric contraction; UT, Upper trapezius; LT, Lower trapezius; YE, Y-raise exercise; YET, Y-raise exercise on togu jumper; YEF, Y-raise exercise on a foam roller. *significant difference (p < 0.017).*

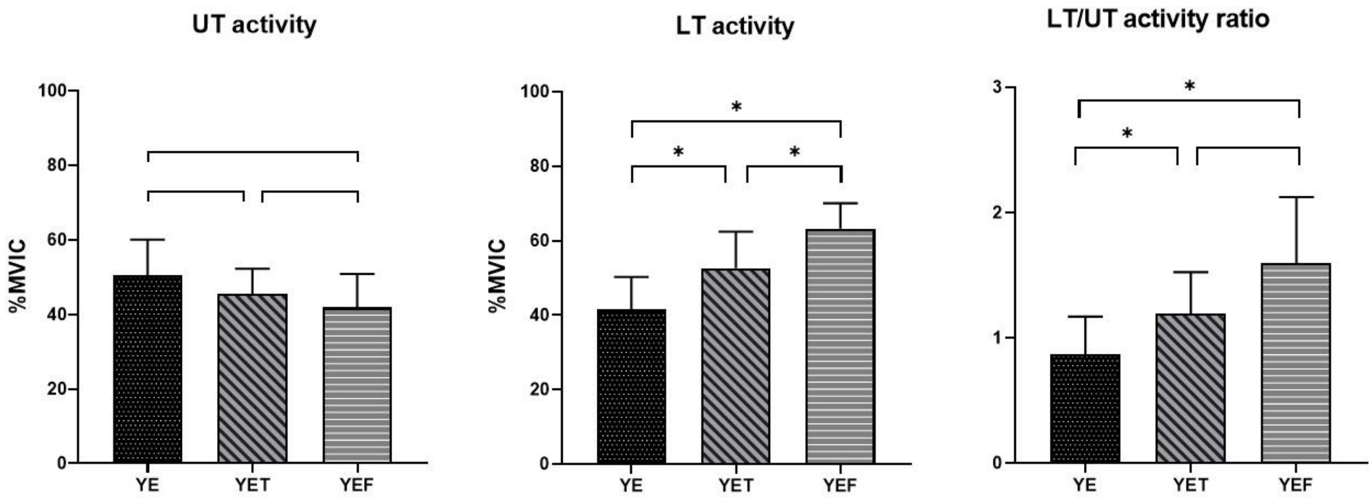

FIGURE 3. Changes in muscle activity for three different bases of support. UT activity, upper trapezius activity; LT activity, lower trapezius activity; LT/UT, lower trapezius/upper trapezius. *Significant difference. %MVIC, percentage maximal voluntary isometric contraction; YE, Y-raise exercise; YET, Y-raise exercise on togu jumper; YEF, Y-raise exercise on foam roller.

TABLE 3. LT/UT muscle activity ratio according to three different Y-raise exercises (n = 15).

	Conditions			*F*	*p*
	YE	YET	YEF		
LT/UT	0.87 ± 0.30	1.19 ± 0.33	1.60 ± 0.53	8.00	0.005*

Mean ± standard deviation.
*UT, Upper trapezius; LT, Lower trapezius; YE, Y-raise exercise; YET, Y-raise exercise on togu jumper; YEF, Y-raise exercise on a foam roller. *significant difference ($p < 0.017$).*

to SFPUS and SFQPS due to the increasingly unstable BOS created by positioning the Swiss ball at the sternum [15]. de Oliveira *et al.* [34] compared the impact of weight-bearing surfaces on muscle activation; they reported that performing shoulder flexion exercises on an unstable BOS while bearing weight facilitates muscle recruitment in the shoulder complex compared to performing the same exercise on a stable support surface [34]. Lee and Bae [26] compared the changes in SA activation during the push-up plus exercise using different positioning of the Togu jumper. They examined the effects of using different BOSs with varying stability on the activation of UT and SA: arms on Togu, legs on Togu, and both arms and legs on Togu [26]. The study reported that SA activation was higher in the arms and legs on Togu group (162.05 μV) than in the arms on Togu (70.87 μV) and legs on Togu (42.13 μV) groups [26]. This exercise performed with the arms and legs on Togu increases SA activation compared with the other exercises to maintain stability on an unstable surface [26]. Although direct comparisons with previous studies are challenging, the underlying principle is that performing exercises on an unstable surface requires considerable proximal stability in the shoulder joint. YEF demanded high proximal stability in the LT as the foam roller was positioned from the sternum to the pubic symphysis, creating a smaller contact area and the most unstable BOS for the exercise. This increased the overall LT activation and LT/UT activity ratio compared with those under YE and YET conditions. In contrast, under YET, LT activation was lower than that under YEF but higher than that under YE, likely due to the positioning of the sternum at the center of the Togu jumper (the convex part), which was compressed by the participant's body weight. This compression presumably provided support to the participant's trunk, making it more stable compared with the relatively firm foam roller used during YEF. Consequently, the contact area of the body was larger, leading to relatively lower LT activation during YET compared to YEF.

Notably, there was no statistically significant difference in UT activation under all three exercise conditions. The target bar was set at the same height to standardize shoulder flexion to 180° in the prone position. The UT acts as a prime mover at the initial flexion angles of 0°–30°; subsequently, it transitions to a synergistic muscle to facilitate movement at higher angles. Performing YE at a 160° abduction angle ensures that the UT is not activated as a prime mover [10]. The higher LT/UT activity ratio under YEF compared with that under YE and YET was attributed to the significantly higher LT activation. However, UT activation remained consistent across all exercises. In addition, the increased LT activation likely contributes to spinal stability as part of the core muscles, leading to a higher LT/UT activity ratio during YEF [1, 9, 15]. The LT is involved in scapular depression, upward rotation, and stabilization of the scapulothoracic joint as well as extension of the thoracic vertebrae [1, 9, 15]. According to previous studies, performing push-up exercises on an unstable surface such as a Swiss ball significantly enhances the activation of the rectus abdominis, thereby improving trunk stability [35]. The rectus abdominis is activated through co-contraction, helping the triceps brachii perform the exercise more effectively [35]. Although a direct comparison with previous studies is difficult, the present study suggests that on unstable surfaces such as a foam roller, the core muscles are activated to provide proximal stability, contributing to increased LT activation during YEF.

The present study had certain limitations. First, the study only included healthy males in their 20s, which compromises the generalizability of our findings to individuals of all ages. Further studies should focus on investigating differences across various age groups and sexes using experimental and control designs. Second, the contact area of the BOS was not measured during the three exercise conditions; therefore, the exact contact areas for each exercise could not be confirmed. Further studies should objectively quantify the contact areas to determine the correlation between muscle activation and the contact area of the BOS. Third, the muscle activation of core muscles was not determined. Further studies should be evaluated to compare the activation of shoulder and core muscles. Fourth, the study was conducted using a cross-sectional design. Further studies should be conducted over longer periods to verify the effects of YEF over time. Finally, surface EMG exhibits crosstalk effects during the exercises.

5. Conclusions

The present study compared UT and LT activation as well as the LT/UT activity ratio during three different exercises performed in the prone position. YEF showed a statistically significant increase in LT activation and LT/UT activity ratio compared with YE and YET. Therefore, YEF can be recommended for selectively enhancing LT activation and improving the LT/UT activity ratio in healthy male subjects.

AVAILABILITY OF DATA AND MATERIALS

The data presented in the present study are available on reasonable request from the authors.

AUTHOR CONTRIBUTIONS

ICJ—designed the research study. SYB, THK and ICJ—performed the research; analyzed the data, and wrote the manuscript. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Institutional Review Board of Hoseo University (1041231-240820-HR-184). Before conducting the research, written informed consent was obtained from all participants. The study adhered to the principles outlined in the Declaration of Helsinki.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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