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# Theraband Applications for Improved Upper Extremity Wall-Slide Exercises

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***Context:*** The wall-slide exercise is commonly used in clinic and research settings. Theraband positioning variations for hip exercises have been investigated and used, but Theraband positioning variations for upper extremity wall-slide exercises, although not commonly used, have not been examined.

***Objective:*** To evaluate the effect of different Theraband positions (elbow and wrist) on the activation of the scapular and shoulder muscles in wall-slide exercises and compare these variations with each other and with regular wall-slide exercises for the upper limbs.

***Design:*** Descriptive laboratory study.

***Setting:*** University laboratory.

***Patients or Other Participants:*** A total of 20 participants (age = 23.8 ± 3 years, height = 176.5 ± 8.14 cm, mass = 75.3 ± 12.03 kg, body mass index = 24.23 ± 4.03) with healthy shoulders.

***Intervention(s):*** Participants performed wall-slide exercises (regular and 2 variations: Theraband at the elbow and Theraband at the wrist) in randomized order.

***Main Outcome Measure(s):*** Surface electromyographic activity of the trapezius (upper trapezius [UT], middle trapezius [MT], and lower trapezius [LT]), infraspinatus, middle deltoid (MD), and serratus anterior (SA) muscles.

***Results:*** Regular wall-slide exercises elicited low activity in the MD and moderate activity in the SA muscles (32% of maximal voluntary isometric contraction [MVIC] in the SA), whereas the Theraband-at-elbow and Theraband-at-wrist variations elicited low activity in the MT, LT, infraspinatus, and MD muscles and moderate activity in the SA muscle (46% and 34% of MVIC in the SA, respectively). The UT activation was absent to minimal (classified as 0% to 15% of MVIC) in all wall-slide exercise variations. The Theraband-at-wrist variation produced lower UT:MT, UT:LT, and UT:SA levels compared with the regular wall-slide exercise and Theraband-at-elbow variation.

***Conclusions:*** In shoulder rehabilitation, clinicians desiring to activate the scapular stabilization muscles should consider using the Theraband-at-wrist variation. Those seeking more shoulder-abduction activation and less scapular stabilization should consider using the Theraband-at-elbow variation of the upper extremity wall-slide exercise.

***Key Words:*** shoulder, electromyography, superficial back muscles, exercise therapy, rehabilitation

**Key Points**

- To achieve scapular stabilization, clinicians should use the Theraband-at-wrist variation of the upper extremity wall-slide exercise.
- To focus more on shoulder abduction, clinicians should use the Theraband-at-elbow variation of the upper extremity wall-slide exercise.
- Theraband variations of the upper extremity wall-slide exercise can be used in clinical settings for a more goal-oriented approach.

The scapulothoracic joint is a physiological joint that is stabilized by dynamic muscular forces working in harmony.[1] This harmony is crucial for the smooth and healthy movements of the scapula and arm, as they provide a stable base for the glenohumeral joint.[2,3] The scapulothoracic and glenohumeral muscles, mainly the trapezius, serratus anterior (SA), levator scapulae, rhomboid major, and pectoralis minor, supply this stability and mobility.[4] These muscles are challenged most during humeral elevation, and changes in strength, activation, or both can cause scapulothoracic dysfunction. Such dysfunction, with reduced glenohumeral and acromiohumeral distances, could make the shoulder complex vulnerable to injury, as repetitive use may result in pathologic conditions such as shoulder pain, shoulder subacromial and internal impingement, and rotator cuff tendinopathy.[5–8]

Scapulothoracic dysfunction is related to lower electromyographic (EMG) activity levels in the middle trapezius (MT), lower trapezius (LT), and SA muscles.[9] Another important factor to consider in shoulder rehabilitation is upper trapezius (UT) activity, as excess UT activation has been proposed to contribute to abnormal scapular motion.[10] In overhead motion, the infraspinatus (IS) muscle produces an approximation force to resist distraction of the glenohumeral joint, which plays a critical role in dynamic stability.[11] Clinicians prescribe exercises specifically targeting these muscles to restore harmony and quality in scapular movements during shoulder rehabilitation.[12] For

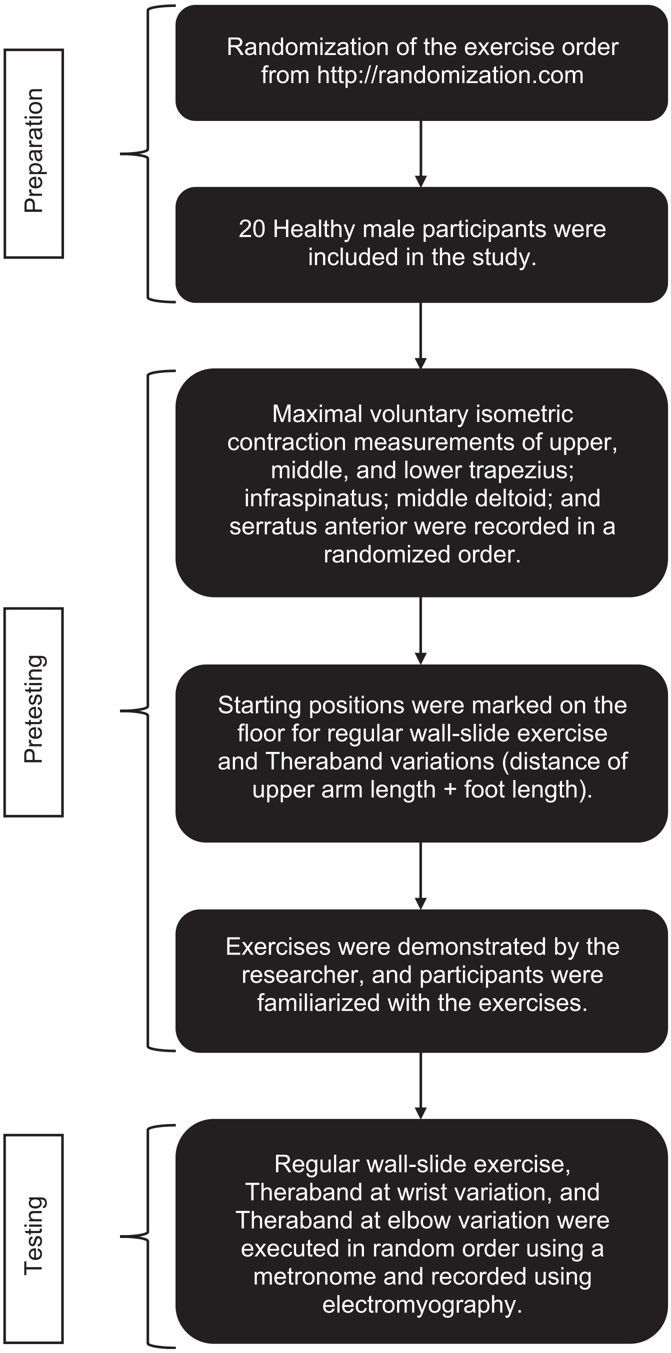


**Figure 1. Study flowchart.**

this purpose, the wall-slide exercise is recommended in shoulder elevation of $\geq 90°$.[9,13] Variations of the wall-slide exercise exist: for 1 variation, Castelein et al[12] used a Theraband (Performance Health) at hand level to elicit more external-rotation force.[14–17] Using elastic resistance bands stimulates specific muscle activations, and a change in the resistance band's position alters the activation of the targeted muscles.[18,19] As suggested by the literature, using Theraband resistance bands at different positions could change the activation levels of the muscles and, thus, the aim of the exercise itself.

Therefore, the purpose of our study was to investigate the effect of different Theraband positions (elbow and wrist) on the activation levels of the scapular and shoulder muscles in wall-slide exercises and compare these variations with each other and a regular wall-slide exercise. Our primary hypothesis was that the location of the resistance band would produce different muscle activations in different exercise phases (ascending, stationary, and descending) of the wall-slide exercise. Our secondary hypothesis was that this difference in muscle activations would produce different muscle-activation ratios.

## METHODS

### Participants

We recruited 20 healthy male participants who were physically active but did not exercise regularly (Figure 1). We defined *physically active* as participating in $\geq$150 minutes of moderate-intensity physical activity or 75 minutes of vigorous-intensity physical activity each week. We defined *regular exercise* as exercising professionally or recreationally under supervision; following a guideline for strength building, cardiovascular, or fitness purposes (ie, shoulder strengthening in a gymnasium 3 times per week); or all of these. Our inclusion criteria were age 18 to 40 years, no restrictions in the glenohumeral joint (ie, no range-of-motion limitation in goniometric measurement of the shoulder), no shoulder pain or instability within 6 months of the study, no injury to the shoulder joint within 6 months of the study, no history of surgery to the shoulder or cervical regions, symmetric scapular movement (visually classified as Kibler type 4[20] by a physiotherapist with 22 years of experience [İ.D.]), and no systemic or neurologic diseases. All participants provided written informed consent, and the Hacettepe University Ethics Boards and Commissions approved our study (No. 2019/22-33, approved September 17, 2019).

### Outcome Measures

Before data collection, we recorded each participant's demographic information (age, height, weight, and body mass index) and dominant side. The *dominant hand* was determined by asking which hand was used for writing.

### Electromyography

A surface EMG system with 8 channels (TeleMyo DTS System; Noraxon USA) was used to measure muscle-activation levels. Sites for the dominant-side electrode attachment were shaved, scrubbed, and cleansed with 70% isopropyl alcohol. The sampling rate for data collection was 1500 Hz. The device had a common-mode rejection ratio of 80 dB, and gain was set at 1000.[21,22] A synchronized video record (model C920; Logitech) was taken at 50 frames per second to identify 3 phases of the exercises (*ascending phase*: from starting to finishing position; *stationary phase*: hold at the finishing position; *descending phase*: from finishing to starting position).

The same examiner (Ö.U.) placed bipolar Ag-Cl surface electrodes (model Plusmed; Trimpeks) over the UT, MT, LT, IS, middle deltoid (MD), and SA of all participants. We followed the "Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles" (SENIAM) recommendations for electrode placement and interelectrode distance.[12,21–24]

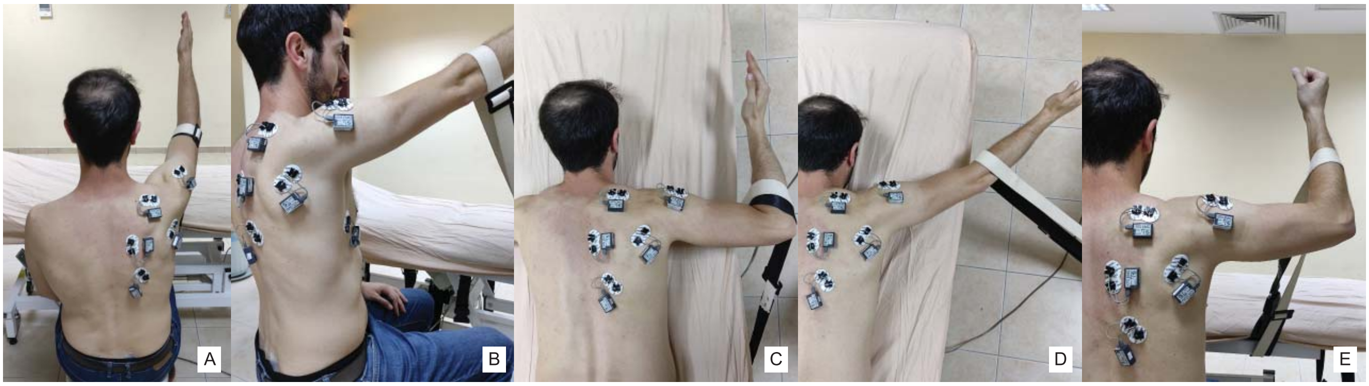


**Figure 2. A and B, Maximal voluntary isometric contraction positions for the upper trapezius, middle deltoid, and serratus anterior from 2 perspectives showing electrode placement. Positions for the, C, middle trapezius, D, lower trapezius, and E, infraspinatus.**



Electrodes for the UT were placed halfway between the spinous process of C7 and the posterior acromion[23]; for the MT, halfway between the medial border of the scapula and the spinous process of T3[14]; for the LT, at 2/3 of the line from the trigonum spinae to T8[12]; for the IS, parallel to and approximately 4 cm below the scapular spine, on the lateral aspect over the infrascapular fossa[25]; for the MD, on a line from the acromion to the lateral epicondyle of the elbow, corresponding to the greatest bulge of the muscle[5]; and for the SA, horizontally just below the axillary area, at the level of the inferior tip of the scapula and just medial to the latissimus dorsi.[25] Additionally, a 2-sided band was used to affix the electrodes.

## Testing Procedure

In the first part of the investigation, we quantified maximal voluntary isometric contractions (MVICs) of the UT, MT, LT, IS, MD, and SA muscles in randomized order. Each MVIC measurement lasted at least 5 seconds and was repeated 3 times against a fixed-belt resistance band with a 30-second rest between contractions and a 2-minute rest between tests of MVICs of different muscles. The same researcher (A.S.A.) orally encouraged participants to give their maximal effort.[12,22]

The MVICs of the UT, MD, and SA were measured using resisted arm elevation. Participants sat with the upper extremity flexed forward in 125° of flexion, and resistance was applied using a fixed belt crossing just over the elbow.[26] For the MVIC measurements of the MT, participants lay prone with the dominant arm abducted to 90° and externally rotated. Resistance was applied vertically using a fixed belt just above the elbow joint.[26] For the MVIC measurements of the LT, participants lay prone with the dominant arm abducted to 140° and externally rotated. Resistance was applied toward additional flexion and parallel to the LT fibers using a fixed belt just above the elbow joint.[26] For the MVIC measurements of the IS, participants sat with the arm abducted to 90° and externally rotated to 45° and the elbow flexed to 90°. They were asked to pull obliquely against a belt positioned at wrist level (Figure 2).[27]

After MVIC recording, the starting position was standardized because participants would have to move away from their location between the regular and Theraband wall-slide variations. To determine this position, we measured the individual's upper arm and foot lengths and applied a tape to the floor, marking the total distance of upper arm and foot lengths for the starting position. For the starting position, each person was asked to stand behind this line and position the shoulders in 90° of flexion in the scapular plane, the elbows in 90° of flexion, and the forearms in midrotation so the ulnar side of the forearm was in contact with the wall. Before exercise trials, the starting and finishing positions of the arms (90° and 150° of shoulder flexion, respectively, in the scapular plane) were marked on the wall using colored tape. For exercise execution, participants were asked to begin at the starting position and slide their forearms on the wall to the ending position in 3 seconds, hold this position for 3 seconds, and return to the starting position in 3 seconds.[15] To ensure that the exercises were performed accurately, we used a metronome set at 60 beats/minute. For each exercise, we first described and performed the exercise, and then participants performed the exercise for 3 trials. A 1-minute rest was given between trials, and all exercises were executed in randomized order and recorded using a synchronized camera (model C500; Logitech). We used the http://randomization.com website to randomize exercise order.

To perform the regular wall-slide exercise, participants placed their forearms on the wall with their arms in the scapular plane and slid their arms to maximal shoulder flexion, held the position for 5 seconds, and slid their arms back to the starting position. Resistance of 3.7 lb (1.67 kg) for 100% and 5.5 lbs (2.48 kg) for 200% elongation was used for 2 Theraband variations of the wall-slide exercise. For these variations, the Theraband was tied circumferentially without any slack or tension to the designated area while the individual's upper extremities were positioned next to the body with the elbows flexed to 90° and the hands placed at shoulder width. At the beginning of the exercises, each person placed his arms in the scapular plane, which created tension on the Theraband, and was asked to maintain the tension on the Theraband throughout the exercise. In the first variation, Theraband resistance was applied at the elbow level (Theraband-at-elbow variation), just distal to the elbow joint, to exert a horizontal-abduction force and achieve more MT activation.[28] In the second variation, Theraband resistance was applied at the wrist level (Theraband-at-wrist variation) to exert an external-rotation force and achieve more IS activation (Figure 3).[11]

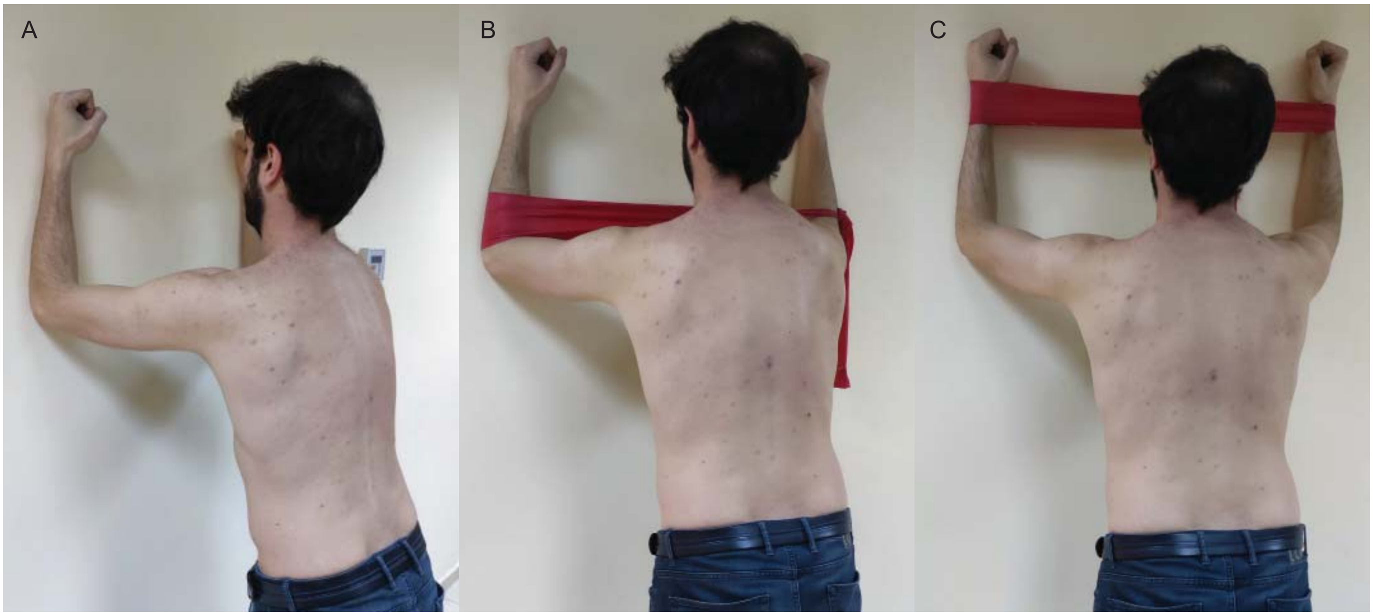


**Figure 3. Three variations of the wall-slide exercise: A, regular, B, Theraband (Performance Health) at the elbow, and C, Theraband at the wrist.**

## Signal Processing and Data Analysis

For signal processing, we used MyoResearch XP Master Edition software (Noraxon USA). The EMG signals were filtered using a 20-Hz high-pass Butterworth filter, and cardiac artifact reduction (50 Hz) was performed. Full-wave rectification and smoothing (root mean square, window = 100 milliseconds) of the signals were performed. Synchronized video recordings tracked the ascending, stationary, and descending phases of all exercise repetitions. The EMG data of the 3 trials were averaged for normalization in each phase and expressed as a percentage of MVIC (%MVIC). The muscle-activation levels of 0% to 15% were classified as *absent to minimal*; 16% to 30%, as *low*; 31% to 60%, as *moderate*; and >60%, as *high*.[24]

We calculated muscle-activation ratios by dividing the %MVIC of the UT by the %MVICs of the MT, LT, and SA. A ratio >1.00 indicated that the UT was more active than the other scapular stabilizers. In rehabilitation, a lower ratio of scapular stabilization muscles to the UT is desirable.[29]

## Statistical Analysis

All outcome variables were normally distributed, as assessed using visual (histograms and probability plots) and analytical (Shapiro-Wilk tests) methods. Patient characteristics and descriptive data for EMG were expressed as mean ± SD. Muscle-activition ratios were compared using the Friedmann test. Post hoc comparisons between exercise variations were conducted using the Wilcoxon signed rank test with Bonferroni correction. To compare muscle activity among the exercises, we applied a 2-way, repeated-measures design to compare exercise-by-muscle (3 × 6) and muscle-by-phase (3 × 3) interactions. When the Mauchly test of sphericity was significant, the Greenhouse-Geisser correction was implemented. Post hoc pairwise comparisons with Bonferonni correction were performed. The $\alpha$ level was set at .05. We used SPSS (version 26; IBM Corp) for statistical analysis.

## RESULTS

Twenty healthy, right-hand–dominant individuals (age = 23.8 ± 3 years, height = 176.5 ± 8.14 cm, mass = 75.3 ± 12.03 kg, body mass index = 24.23 ± 4.03) participated in our study. Mean ± SD EMG values for muscles during the exercise variations are given in Table 1.

## Muscle-Activation Ratio Comparisons

Theraband variations produced different UT : MT, UT : LT, and UT : SA muscle-activation ratios in all 3 phases ($\chi^2$ range = 0.18–0.35; $P$ values < .001). Muscle-activation ratios for the UT : MT, UT : LT, and UT : SA for the exercise variations are shown in Table 2.

## Comparisons Among Exercise Phases

Statistical analysis showed an interaction effect of muscle by phase for all variations of the wall-slide exercise (regular exercise: $P < .001$, power = 0.99; Theraband at elbow: $P < .001$, power = 0.94; Theraband at wrist: $P < .001$, power = 0.98). The activation levels of all muscles differed among all phases ($P < .05$) with some exceptions. In the regular wall-slide exercise, we observed no differences between the stationary and descending phases for the MT, LT, and IS muscles and between the ascending and stationary phases for the SA muscle. In the Theraband-at-elbow variation, we found no differences between the stationary and descending phases for the UT, MD, and SA muscles. In the Theraband-at-wrist variation, no differences were present between the stationary and descending phases for the UT, IS, and SA muscles and between the ascending and stationary phases for the MD muscle (Figure 4).

## Comparisons Among Exercise Variations

An interaction effect of exercise by muscle was present for all 3 phases ($P < .01$, power = 0.99 for all). In all phases, both variations produced better MT, LT, and IS activation than did the regular wall-slide exercise ($P < .01$ for both). In the ascending phase, the Theraband-at-wrist variation demonstrated higher IS ($P < .001$) and SA ($P = .006$) activation than did the regular wall-slide exercise, and the Theraband-at-elbow variation produced higher MD activation than did the Theraband-at-wrist variation ($P = .003$). In the stationary phase, the Theraband-at-wrist variation produced higher LT, IS, and SA activation than did the regular wall-slide exercise ($P < .01$ for all), and the Theraband-at-elbow variation produced generated higher greater MD activation than did the Theraband-at-wrist variation ($P = .003$). In the descending phase, the Theraband-at-wrist variation led to higher IS activation compared with the regular exercise and the Theraband-at-elbow variation ($P < .001$ for both), and the Theraband-at-elbow variation produced higher MD activation compared with the regular exercise ($P = .01$) and the Theraband-at-wrist variation ($P = .03$). Results of the post hoc tests are displayed in Table 3.

**Table 1. Maximal Voluntary Isometric Contraction for Wall-Slide Exercise Variations, Mean ± SD, %**

| | Wall-Slide Exercise Phase | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Regular | | | Theraband[a] at Wrist | | | Theraband at Elbow | | |
| Muscle | Ascending | Stationary | Descending | Ascending | Stationary | Descending | Ascending | Stationary | Descending |
| Upper trapezius | 11.54 ± 5.19 | 7.37 ± 4.68 | 4.13 ± 3.13 | 7.43 ± 5.01 | 3.22 ± 3.33 | 3.12 ± 2.98 | 11.18 ± 5.36 | 5.31 ± 4.3 | 5.11 ± 4.25 |
| Middle trapezius | 10.31 ± 8.87 | 4.92 ± 3.78 | 4.57 ± 3.33 | 24.70 ± 19.85 | 12.32 ± 11.68 | 16.64 ± 15.19 | 24.3 ± 16.2 | 10.99 ± 7.45 | 16.33 ± 13.14 |
| Lower trapezius | 11.18 ± 8.48 | 5.85 ± 5.95 | 6.24 ± 5.67 | 22.67 ± 11.61 | 12.17 ± 9.09 | 16.74 ± 9.32 | 18.85 ± 10.2 | 9.11 ± 7.39 | 14.88 ± 9.4 |
| Infraspinatus | 13.92 ± 7.89 | 8.43 ± 5.23 | 8.81 ± 6.7 | 29.53 ± 16.67 | 19.95 ± 13.07 | 21.86 ± 10.88 | 22.3 ± 11.75 | 12.47 ± 7.22 | 16.6 ± 9.59 |
| Middle deltoid | 16.42 ± 8.9 | 14.8 ± 8.93 | 8.43 ± 5.61 | 15.26 ± 13.6 | 14.2 ± 14.34 | 10.06 ± 11.61 | 24.23 ± 18.59 | 17.47 ± 9.54 | 16.01 ± 13.22 |
| Serratus anterior | 32.12 ± 21.03 | 20.38 ± 15.69 | 14.44 ± 9.08 | 46.29 ± 37.37 | 27.87 ± 24.62 | 20.51 ± 10.74 | 34.03 ± 19.61 | 19.8 ± 13.03 | 18.35 ± 12.04 |

[a] Performance Health.

## DISCUSSION

During shoulder exercises, the MT, LT, and SA muscles are targeted because of their roles in scapular stabilization and energy transfer.[30] When increasing the activation of these, increased UT activation is not beneficial, as it causes a decrease in the activation of other scapular muscles.[10,31] We noted that the Theraband-at-wrist variation produced the lowest UT : MT, UT : LT, and UT : SA ratios and the highest IS activation. These findings confirmed our initial hypotheses that different Theraband positions would produce different muscle activations in the scapular and shoulder muscles, and different muscle activations would result in different muscle-activation ratios.

We showed that the wall-slide exercise using the Theraband at either the elbow or wrist required moderate (ie, 31% to 60% of MVIC) SA muscle activation and low (ie, 16% to 30% of MVIC) MT, LT, and IS activation in the ascending phase; low SA and IS muscle activation in the stationary phase; and low SA, MT, and IS activation in the descending phase. All variations of the wall-slide exercise required absent to minimal (ie, 0% to 15% of MVIC) UT activation. Both variations activated the scapular stabilization muscles more than the regular wall-slide exercise did, and although the Theraband-at-wrist variation generated better UT : MT, UT : LT, and UT : SA levels and IS activation, the Theraband-at-elbow variation focused more on the MD muscle.

The regular wall-slide exercise produced similar trapezius muscle-activation values to and slightly higher SA activation values than those reported by Castelein et al[17] (mean difference = ±3% MVIC) and a slightly higher IS muscle-activation (mean difference = 4.07% MVIC) value than identified by Wise et al.[16] Theraband variations elicited greater activity in the MT, LT, and IS in all phases and in the SA in the descending phase compared with our regular wall-slide exercise and with the findings of Castelein et al[17] and Wise et al[16] (differences ranged from 3.92% to 15.61% of MVIC). This higher activation in the scapular dynamic stabilization muscles (ie, the MT, LT, and SA) can be explained by the Theraband producing additional forces that challenge scapular stabilization. The higher IS activation can be explained by the Theraband

Table 2. Muscle-Activation Ratio Comparisons

| Ratio[a] | Phase | Wall-Slide Exercise: Regular | Theraband[b] at Wrist | Theraband at Elbow | $\chi^2$ Value | $P$ Value[c] |
|---|---|---|---|---|---|---|
| Upper:middle trapezius | Ascending | 2.32 | 0.75[d] | 0.87[d] | 0.31 | <.001 |
| | Stationary | 2.47 | 0.62[e] | 0.82[d] | 0.35 | <.001 |
| | Descending | 1.44 | 0.39[e] | 0.57[d] | 0.24 | <.001 |
| Upper:lower trapezius | Ascending | 2.86 | 0.61[e] | 0.92[d] | 0.31 | <.001 |
| | Stationary | 3.65 | 0.42[e] | 0.95[d] | 0.4 | <.001 |
| | Descending | 1.36 | 0.33[e] | 0.52[d] | 0.31 | <.001 |
| Upper trapezius:serratus anterior | Ascending | 0.51 | 0.24[e] | 0.45 | 0.2 | <.001 |
| | Stationary | 0.56 | 0.18[d] | 0.44 | 0.27 | <.001 |
| | Descending | 0.35 | 0.18[d] | 0.55 | 0.18 | <.001 |

[a] Friedmann test was used to compare ratios of 3 exercise types.
[b] Performance Health.
[c] Bonferroni correction was applied for post hoc comparisons.
[d] Different from the regular wall-slide exercise ($P < .05$).
[e] Different from the regular and Theraband-at-elbow wall-slide exercises ($P < .05$).

causing an internal-rotation moment.[19] In all 3 phases, the Theraband-at-elbow variation and regular wall-slide exercise elicited more UT activation (difference ranging from 1.01% to 4.11% MVIC) than did the Theraband-at-wrist variation. The Theraband-at-wrist variation elicited a scapular internal-rotation moment in addition to a shoulder downward-rotation moment, which might explain the lower UT activation.[19]

The regular wall-slide exercise and the Theraband-at-elbow variation produced UT : SA activation ratios that were similar to each other and to those reported in the literature.[10] The Theraband-at-wrist variation resulted in the lowest UT : SA ratios, which could reflect higher SA activation and lower UT activation. Similar UT, MT, and LT activation levels (mean difference = ±5% of MVIC) were noted by Castelein et al,[17] who investigated bilateral shoulder elevation with resisted external rotation. However, we observed higher SA activation (mean difference = 23.79% of MVIC) levels that were probably caused by differences in exercise execution; their exercise was open kinetic chain, and ours was closed kinetic chain, with participants using a small enough weight to comfortably slide the arms on the wall. Given that exercises with higher MT, LT, and SA activations are beneficial to shoulder

Table 3. Post Hoc Pairwise Comparisons of Total Mean Normalized Electromyographic Activity for Wall-Slide Exercises[a]

| Phase and Muscle | Comparison: Regular Versus Theraband at Wrist: Mean Difference ± SE, %MVIC | $P$ Value | Regular Versus Theraband at Elbow: Mean Difference ± SE, %MVIC | $P$ Value | Theraband at Wrist Versus Elbow: Mean Difference ± SE, %MVIC | $P$ Value | Clinical Conclusion |
|---|---|---|---|---|---|---|---|
| Ascending | | | | | | | Theraband variations → ↑MT, LT, and IS activation levels vs the regular wall-slide exercise. Theraband-at-wrist variation →↑IS, LT, and SA activation and ↓UT activation. Theraband-at-elbow variation →↑MD activation. |
| UT | 4.1 ± 1.03 | <.001[b] | 0.359 ± 0.787 | .65 | −3.75 ± 1.03 | .002[b] | |
| MT | −14.39 ± 2.78 | <.001[b] | −13.99 ± 2.11 | <.001[b] | 0.402 ± 1.79 | .83 | |
| LT | −11.49 ± 1.44 | <.001[b] | −7.77 ± 1.14 | <.001[b] | 3.82 ± 1.09 | .002[b] | |
| IS | −15.61 ± 2.27 | <.001[b] | −8.38 ± 1.22 | <.001[b] | 7.23 ± 1.96 | .002[b] | |
| MD | 1.17 ± 2.07 | .58 | −7.81 ± 3.78 | .05 | −8.98 ± 2.65 | .003[b] | |
| SA | −14.17 ± 4.61 | .006[b] | −1.91 ± 1.9 | .33 | 12.26 ± 4.99 | .02[b] | |
| Stationary | | | | | | | Theraband variations → ↑MT, LT, and IS activation levels vs the regular wall-slide exercise. Theraband-at-wrist variation →↑IS, LT, and SA activation and ↓UT activation. Theraband-at-elbow variation →↑MD activation. |
| UT | 4.11 ± 1.03 | <.001[b] | 0.359 ± 0.787 | .65 | −3.75 ± 1.03 | .002[b] | |
| MT | −14.39 ± 2.78 | <.001[b] | −13.99 ± 2.11 | <.001[b] | 0.402 ± 1.79 | .83 | |
| LT | −11.49 ± 1.44 | <.001[b] | −7.67 ± 1.14 | <.001[b] | 3.82 ± 1.09 | .002[b] | |
| IS | −15.61 ± 2.27 | <.001[b] | −8.38 ± 1.22 | <.001[b] | 7.23 ± 1.96 | .002[b] | |
| MD | 1.17 ± 2.07 | .58 | −7.81 ± 3.78 | .05 | −8.98 ± 2.65 | .003[b] | |
| SA | −14.17 ± 4.61 | .006[b] | −1.91 ± 1.9 | .33 | 12.26 ± 4.99 | .02[b] | |
| Descending | | | | | | | Theraband variations → ↑MT, LT, and IS activation levels vs the regular wall-slide exercise. Theraband-at-wrist variation →↑IS activation. Theraband-at-elbow variation →↑MD activation. |
| UT | 1.01 ± 0.4 | .02[b] | −0.983 ± 0.489 | .06 | −1.99 ± 0.45 | <.001[b] | |
| MT | −12.07 ± 2.9 | <.001[b] | −11.76 ± 2.42 | <.001[b] | 0.309 ± 1.67 | .86 | |
| LT | −10.5 ± 1.57 | <.001[b] | −8.64 ± 1.31 | <.001[b] | 1.86 ± 1.09 | .10 | |
| IS | −13.05 ± 1.84 | <.001[b] | −7.79 ± 1.17 | <.001[b] | 5.26 ± 1.08 | <.001[b] | |
| MD | −1.62 ± 2.24 | .48 | −7.58 ± 2.77 | .01[b] | −5.96 ± 2.58 | .03[b] | |
| SA | −6.07 ± 1.57 | <.001[b] | −3.92 ± 1.65 | .03[b] | 2.15 ± 1.88 | .27 | |

Abbreviations: IS, infraspinatus; LT, lower trapezius; MD, middle deltoid; MT, middle trapezius; MVIC, maximal voluntary isometric contraction; SA, serratus anterior; UT, upper trapezius.

[a] Values are given as the mean difference between exercise means (regular − Theraband [Performance Health] variation; Theraband at wrist − Theraband at elbow).
[b] Indicates difference ($P < .05$).

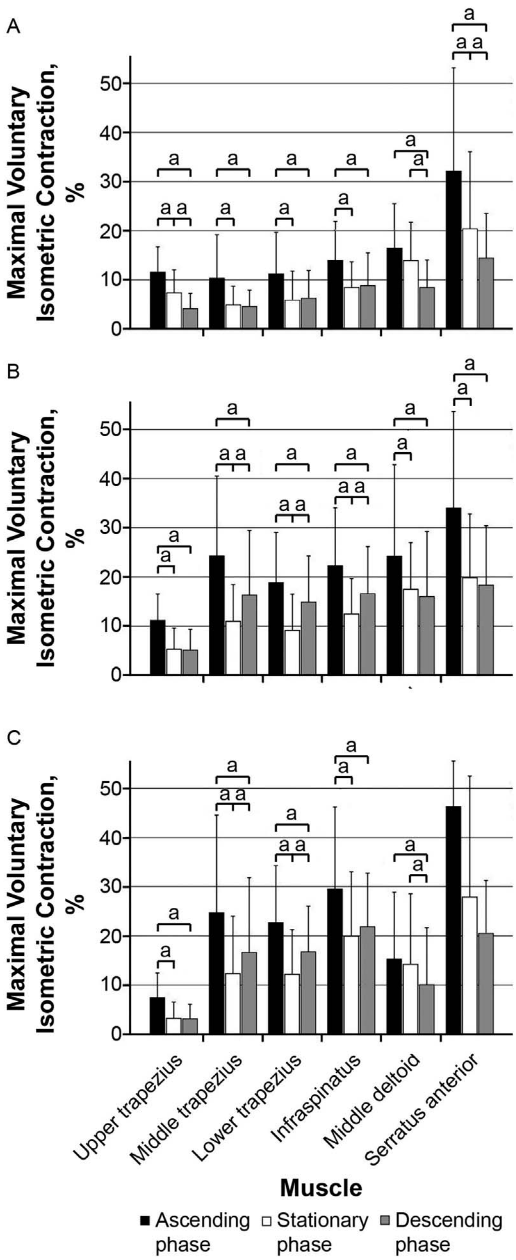


**Figure 4. Muscle-activation (mean ± SD) comparison of different phases by muscle for the 3 variations of the wall-slide exercise: A, regular, B, Theraband (Performance Health) at the elbow, and C, Theraband at the wrist. [a] Indicates difference.**

stabilization, the Theraband-at-wrist variation of the wall-slide exercise seems to be a better choice.[12,15,17,24,30]

Different positioning of the Theraband may change the lever arm of the force, which alters the activation of the targeted muscles.[3,19] Cambridge et al[18] used different resistance-band positionings and produced progressive resistance for hip muscles. In our study, the Theraband-at-wrist variation not only increased the resistance but also may have produced rotatory forces in the shoulder that caused higher LT and SA activations compared with other exercises. In addition, given that the LT and UT muscles are synergists, higher activation of the LT muscle might have caused the UT muscle to activate less. Conversely, the Theraband-at-elbow produced resistance to the shoulder muscles and the abductors, which caused the highest MD activity in most phases. Generally, in the descending phase, gravitational forces lessen the load on the shoulder and scapular muscles and could also lower the EMG activations, as this is an eccentric phase.[32,33] This might have resulted in less load on the scapular muscles, which (1) diminished the LT activation difference between Theraband variations and (2) decreased SA activation levels. Although the SA activation levels decreased, they were higher than those during the regular wall-slide exercise, as the Theraband put more load on the SA muscles. Based on the activation levels and ratios, clinicians can use the Theraband-at-wrist variation to focus mostly on the scapular stabilization muscles (MT, LT, and SA) and the IS and can use the Theraband-at-elbow variation to focus on the MD while still activating the scapular stabilization muscles and the IS.

Muscle-activation patterns by phase differed slightly among exercise variations. In all variations of the wall-slide exercise (including the regular exercise), the ascending phase was the most demanding, and the descending phase was the least demanding.[32,33] Theraband variations created additional loads that altered this phase order (ie, the Theraband-at-wrist variation altered LT activation to higher levels and the Theraband-at-elbow variation altered MD activation to higher levels in the descending phase). The UT activation was similar for all exercises.

Additional loading using the Theraband led to different activation levels in the muscles, depending on the Theraband position.[18,19] Positioning of the Theraband on the wrist might have generated rotatory forces, causing higher LT activation, and positioning of the Theraband on the elbow might have caused adduction forces in the shoulder, resulting in higher MD activation. Based on the activation levels and ratios, the Theraband-at-wrist variation is beneficial for achieving higher activation in the scapular stabilization muscles (MT, LT, and SA) and the IS, whereas the Theraband-at-elbow variation is beneficial for achieving higher activation in the MD while still challenging the scapular stabilization muscles (MT, LT, and SA) and the IS.

Our study had limitations. Our sample pool consisted of healthy male participants with no shoulder pain during activities of daily living. Although individuals with mild shoulder dysfunction have similar activation patterns as those of healthy individuals in other exercises, the wall-slide exercise should be investigated in patients with shoulder pain.[13] The Theraband variations may have altered shoulder and scapular kinematics. Analyzing the scapular and shoulder kinematics simultaneously with the Theraband variations could be useful for identifying changes. Another limitation was the use of surface EMG. We followed the "Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles" guidelines and recommendations,[12,21–24] but cross-talk could have affected the measurements.

## CONCLUSIONS

Compared with the low (16% to 30% of MVIC) to moderate (31% to 60% of MVIC) activation levels in the scapular muscles, MD, and IS associated with the regular wall-slide exercise, the wall-slide exercise variations elicited higher activation levels. The Theraband-at-wrist variation is preferred for focusing on the scapular stabilization (MT, LT, and SA) and IS muscles, as it produced the lowest UT : MT, UT : LT, and UT : SA ratios. The Theraband-at-elbow variation is preferred for focusing on the MD while activating the scapular stabilization (MT, LT, and SA) and IS muscles. Clinicians can adjust the Theraband positioning to achieve the desired muscle-activation ratios.

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