Possibilities of altering arm and shoulder muscle activation in a static therapeutic climbing exercise through arm position, hand support and wall inclination

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Abstract
The aim of the study was to quantify the activation of arm and shoulder muscles during a static therapeutic climbing exercise and to investigate the possibility of altering the muscle activation through arm position (Jug, Undercling, Sidepull internal rotated, Sidepull external rotated), hand support (one-handed, double-handed) and wall inclination (0°, 12°). Electromyographic (EMG) activity of 14 healthy, climbing unexperienced males for the right m. biceps brachii (BB), m. serratus anterior (SA), m. upper, middle and lower trapezius (UT, MT, LT) showed mainly low to moderate EMG activation levels (BB: 4.1–40.1% maximum voluntary isometric contraction (MVIC), SA: 4.5–24.5% MVIC, UT: 1.3–28.0% MVIC, MT: 8.6–47.1% MVIC, LT: 3.8–47.3% MVIC). Significant differences occurred between the four arm positions for the UT and LT. The one-handed support revealed significant higher muscle activation than the double-handed support in every condition except for SA in Undercling arm position at 12° wall inclination. Increasing the wall inclination (from 0° to 12° overhang) led to a significant increase in muscle activation in nearly every exercise variation and muscle. These findings suggest that arm position, hand support and wall inclination are appropriate possibilities of altering muscle activation patterns in therapeutic climbing.

Keywords: Biomechanics, rehabilitation, strength, musculoskeletal

Introduction
Therapeutic climbing is a topical prescribed method for preventing or treating health problems. It has been successfully used in the treatment of orthopedic-traumatic diseases (Engbert & Weber, 2011; Heitkamp, Mayer, & Böhm, 1999; Heitkamp, Wörner, & Horstmann, 2005; Kim & Seo, 2015; Muehlbauer, Stuerchler, & Granacher, 2012). Compared to other rehabilitation exercises, the adventurous component likely generates a higher patient compliance. It simultaneously trains the muscle force, mobility and whole-body coordination (Buechter & Rheinländer, 2011; Grzybowski & Eils, 2011; Lazik, Bernstädt, Kittel, & Luther, 2008; Muehlbauer et al., 2012) and seems to be a suitable method for preventing or treating orthopedic-traumatic disease of the shoulder complex. Although therapeutic climbing currently enjoys great popularity, there is only limited scientific background with respect to its effects on the musculoskeletal system (Buechter & Rheinländer, 2011; Grzybowski & Eils, 2011; Lazik et al., 2008).

The glenohumeral joint (GH) in combination with the movement of the sternoclavicular, acromioclavicular and scapulothoracic joint accomplishes the greatest range of motion in the human body. The muscle forces and the timing of the prime movers and stabilizers are important factors to provide a stable base of support during an arm movement (Ludewig & Borstead, 2005). Some authors suggest that alterations in scapulohumeral rhythm respectively in scapular position at rest may be linked to GH pathologies, but there is no
Possibilities of altering arm and shoulder muscle activation

It is widely accepted that exercise variations can be conducted by e.g. altering arm position, contact points at the wall (one vs. two hands on the climbing holds) or wall inclination. But only limited information on the effects of these variations exist for a static therapeutic climbing exercise for the leg and trunk muscles only (Grzybowski, Donath, & Wagner, 2014; Mally, Litzenberger, & Sabo, 2013; Muehlbauer, Granacher, Jockel, & Kittel, 2013; Park, Kim, Kim, & Choi, 2015). In a static therapeutic exercise a wall overhang of 10–12° seems necessary to increase the Electromyographic (EMG) activity of the leg and trunk muscles (Grzybowski et al., 2014; Park et al., 2015). In a vertical level wall releasing one hand off the climbing hold also leads to a significantly increased EMG activity in leg and trunk muscles. Only one study provides information of therapeutic climbing exercises on the trapezius as a muscle important for scapular stabilization, however in a dynamic setting. Muehlbauer et al. (2013) demonstrated that activity levels of the trapezius muscle ranged from 7.8% to 74.2% maximum voluntary isometric contraction (MVIC) demonstrating the enormous potential of movement selection on muscle activation. It is hypothesized, that for the muscles responsible for shoulder stabilization similar effects occur, but to our knowledge, no study has analysed the activation of shoulder muscles during a static therapeutic climbing exercise with dependency on arm position, hand support and wall inclination. In terms of exercise variations in order to control for intensity and easy implementation in a daily therapeutic routine, varying arm position and hand support is a simple way, while changing wall inclination might be a more complex and time consuming variation. Additionally, not every therapist has the opportunity to use an adjustable climbing wall due to the high costs or spatial possibilities. Therefore, the purpose of this study was to quantify and compare in a first step the EMG activity of the BB, SA, UT and LT during four different arm positions of a static therapeutic climbing exercise. Furthermore, it was aimed to analyse the effect of releasing one hand on the muscle activation of the contralateral side. In each variation of arm position and hand support, additionally the influence of wall inclination on the activation of these muscles was investigated. The results of this study might be a relevant tool for generating therapeutic climbing rehabilitation protocols.

Methods

Participants

Fourteen healthy, climbing unexperienced males (age 28.5 ± 8.1 years, body mass 80.7 ± 9.4 kg,
handholds used for this experiment (Roof Jugs L, inclination modification during measurements. The wall inclination adjustment system to facilitate berg, Germany) and both inclinations were saved at Level Plus 25, UMAREX GmbH & Co. KG, Arnsberg, Switzerland). The adhesive bipolar surface electrodes with an inter electrode distance of 20 mm were placed along the presumed direction of the underlying muscle fibres according to the recommendations by SENIAM or similar studies (Cools, Borms, et al., 2014; Ekstrom, Donatelli, & Soderberg, 2003; Hermens, Freriks, Disselhorst-Klug, & Rau, 2000). Skin under the electrodes was shaved and cleaned with alcohol to reduce skin impedance. Additionally, all electrodes, cables and transmitters were fixed with adhesive tape to restrict their movement. A synchronized video was captured during measurements. After electrode placement, each participant performed ten minutes of easy climbing on big climbing holds on the vertical climbing wall for warm-up. During this time, the testing positions were practiced with correction by an experienced therapist.

Data collection for each participant began with a series of isometric contractions for obtaining MVIC. MVIC testing of SA, UT, MT and LT was performed using three shoulder normalization tests recommended by Boettcher et al. (Boettcher, Ginn, & Cathers, 2008). For the BB, resistance was applied to 90° of elbow flexion with the forearm in a supine position (Cools, Borms, et al., 2014). Each MVIC test was performed three times for five seconds with 30 seconds pause between muscle contractions.

After a five-minute resting period to recover from MVIC testing, the participants performed the static therapeutic climbing exercise in four arm position variations with changing hand support (releasing the left hand from the hold) on a 0° and 12° (overhang) inclined climbing wall. The wall inclination angle was measured with a digital goniometer (Digi-Level Plus 25, UMAREX GmbH & Co. KG, Arnsberg, Germany) and both inclinations were saved at the wall inclination adjustment system to facilitate inclination modification during measurements. The handholds used for this experiment (Roof Jugs L, HRT safety holds, Sofia, Bulgaria) were similar symmetrical arranged jugs and characterized by a large 10 cm width and 7 cm deep ridge. The footholds (HRT safety holds, Sofia, Bulgaria) provided a 16 cm wide flat support for the feet at a right angle to the wall sticking out 8 cm. To account for different body-heights and enable similar body position throughout all participants, participants were instructed to either use a lower or 25 cm vertical higher foothold, while the handholds were kept at the same position.

The initial position for measurement was an upright frontal climbing position with both hands on the wall (double-handed support) and both feet on predefined footholds. As soon as participants were in the correct position, the testing started: After five seconds of static holding the participant had to release the left hand 1 cm from the hold and maintain a one-handed static position for further five seconds (one-handed support) while maintaining the initial body position. The time was controlled using a metronome set to 60 beats per minute. During the exercise, participants were not allowed to have knee contact with the wall to omit a further supporting moment of force for maintaining the body position during the one-handed exercise phase. The four arm positions were: Jug position at 90° shoulder abduction and 90° elbow flexion (Figure 1(a)), Undercling position at 0° shoulder abduction and 90° elbow flexion (Figure 1(b)), Sidepull internal rotated (Sidepull_IR) position at 90° shoulder abduction, full elbow flexion and GH IR (Figure 1(c)), and Sidepull external rotated (Sidepull_ER) position at 0° shoulder abduction, 90° elbow flexion and GH external rotation (ER) (Figure 1(d)). The order of arm positions and inclinations was randomized and each participant performed three repetitions of each exercise condition with 30 seconds of rest between each repetition. Between the different arm positions and inclination angles, a resting period of one minute was realized.

Data processing

Data were further processed using Visual 3D (c-Motion Inc., Germantown, USA). The raw EMG data were filtered using a second order Butterworth band pass filter with a frequency range of 10–300 Hz and full-wave rectified. The MVIC data was smoothed using a 250 ms moving average window. Peak values were then identified as MVIC for each muscle. For the exercise trials, the synchronized video was used to identify the change between double-handed and one-handed support. EMG data during the first and the last second of each
support phase was discarded and the average of the remaining three seconds of data of each support phase was calculated. The data were then normalized by expressing the average EMG values as a percentage of the MVIC. This muscle activations expressed in percent MVIC values for each muscle were averaged for the participant’s three repetitions.

Statistical analysis

Statistics were calculated using SPSS 21.0 (SPSS Inc., Chicago, Illinois). An intraclass correlation coefficient (ICC3,1) was used to detect same-day test-retest reliability of the EMG data using the values of the three trials for analysis (Ekstrom et al., 2003; Reinold et al., 2004). To test for statistical differences among arm positions during double-handed support phase at two different inclination angles a two-factor (4 × 2 arm position∗inclination) analysis of variance (ANOVA) for repeated measures was used for every muscle. To test for statistical differences among hand support at two different inclination angles for each arm position and muscle a two-factor ANOVA (2 × 2 hand support∗inclination) for repeated measures was calculated. The level of significance was set at $p \leq .05$. For post-hoc testing, Bonferroni corrected t-tests were used.

Results

Reliability

The same-day test-retest ICCs were mostly moderate to high ranging from 0.21 to 0.99, with a mean (±standard deviation) of 0.88 ± 0.12 (Table I).

EMG activation levels

The EMG activity of each muscle (% MVIC) during the different exercise conditions and the statistical findings are listed in Table II and Figure 2. None of the participants could maintain the one-handed Sidepull_ER position for five seconds. Therefore, no EMG data exists for this exercise variation.

Arm position. During double-handed support, the two-way repeated-measures ANOVA indicated significant main effects across arm positions for UT ($F = 7.7, p = .002$) and LT ($F = 19.0, p < .001$) and significant main effects across inclination angle for BB ($F = 42.9, p < .001$), SA ($F = 7.2, p = .022$), UT

Table I. Intraclass correlation coefficients (ICC3,1) for the EMG measurements for each exercise variation and muscle. Corresponding 95% confidence intervals in brackets

| Exercises          | Inclination [°] | Biceps brachii | Serratus anterior | Lower trapezius | Middle trapezius | Upper trapezius |
|--------------------|----------------|----------------|-------------------|-----------------|------------------|-----------------|
| Jugdbl.            | 0              | 0.69 [0.41, 0.87] | 0.90 [0.76, 0.96] | 0.92 [0.82, 0.97] | 0.85 [0.69, 0.95] | 0.65 [0.36, 0.86] |
|                    | 12             | 0.63 [0.33, 0.84] | 0.89 [0.75, 0.96] | 0.89 [0.76, 0.96] | 0.92 [0.81, 0.97] | 0.79 [0.57, 0.92] |
| Jug_one            | 0              | 0.89 [0.76, 0.96] | 0.93 [0.82, 0.97] | 0.95 [0.88, 0.98] | 0.97 [0.93, 0.99] | 0.85 [0.67, 0.94] |
|                    | 12             | 0.80 [0.60, 0.93] | 0.95 [0.87, 0.98] | 0.96 [0.90, 0.99] | 0.94 [0.86, 0.98] | 0.91 [0.80, 0.97] |
| Underclingdbl.     | 0              | 0.61 [0.30, 0.85] | 0.94 [0.85, 0.98] | 0.92 [0.81, 0.97] | 0.91 [0.80, 0.97] | 0.89 [0.76, 0.96] |
|                    | 12             | 0.79 [0.57, 0.92] | 0.85 [0.63, 0.96] | 0.94 [0.85, 0.98] | 0.98 [0.95, 0.99] | 0.98 [0.95, 0.99] |
| Undercling_one     | 0              | 0.86 [0.69, 0.95] | 0.91 [0.80, 0.97] | 0.96 [0.91, 0.99] | 0.97 [0.94, 0.99] | 0.97 [0.92, 0.99] |
|                    | 12             | 0.85 [0.67, 0.95] | 0.87 [0.68, 0.96] | 0.93 [0.84, 0.98] | 0.97 [0.94, 0.99] | 0.94 [0.87, 0.98] |
| Sidepull_IRdbl.    | 0              | 0.93 [0.85, 0.98] | 0.81 [0.61, 0.93] | 0.95 [0.89, 0.98] | 0.99 [0.98, 0.99] | 0.89 [0.76, 0.96] |
|                    | 12             | 0.88 [0.73, 0.96] | 0.67 [0.37, 0.87] | 0.91 [0.79, 0.97] | 0.97 [0.94, 0.99] | 0.94 [0.85, 0.98] |
| Sidepull_IR_one    | 0              | 0.84 [0.66, 0.94] | 0.78 [0.56, 0.92] | 0.96 [0.92, 0.99] | 0.99 [0.97, 0.99] | 0.89 [0.76, 0.96] |
|                    | 12             | 0.84 [0.65, 0.94] | 0.90 [0.77, 0.97] | 0.96 [0.91, 0.99] | 0.99 [0.98, 0.99] | 0.91 [0.79, 0.97] |
| Sidepull_ERdbl.    | 0              | 0.21 [0.12, 0.61] | 0.90 [0.78, 0.97] | 0.93 [0.83, 0.97] | 0.95 [0.88, 0.98] | 0.69 [0.41, 0.87] |
|                    | 12             | 0.77 [0.54, 0.91] | 0.83 [0.61, 0.94] | 0.93 [0.84, 0.98] | 0.96 [0.91, 0.99] | 0.79 [0.57, 0.92] |

Figure 1. Four different arm positions: Jug (a), Undercling (b), Sidepull_IR (c) and Sidepull_ER (d). Arrows indicating the loading direction on the climbing holds.
Table II. Mean (± standard deviation) electromyographic (EMG) activity expressed as a percentage of MVIC of five shoulder muscles during a quasi-static therapeutic climbing exercise performed in different arm positions (Jug, Underclinging, Sidepull_IR, Sidepull_ER), changing hand support (double-handed and one-handed) and at two different wall inclination angles (0° and 12°).

| Exercises         | Inclination [°] | Biceps brachii | Serratus anterior | Lower trapezius | Middle trapezius | Upper trapezius |
|-------------------|----------------|----------------|-------------------|-----------------|------------------|----------------|
| Jug_dbl.          | 0              | 6.6 ± 4.2      | 4.9 ± 4.1         | 16.2 ± 10.3     | 8.6 ± 6.7        | 1.3 ± 0.8      |
|                   | 12             | 12.0 ± 7.3     | 7.5 ± 6.4         | 23.4 ± 14.4     | 21.0 ± 23.2      | 5.5 ± 3.9      |
| Jug_one           | 0              | 13.2 ± 8.7     | 11.2 ± 9.3        | 27.5 ± 16.1     | 19.6 ± 19.2      | 4.7 ± 3.3      |
|                   | 12             | 27.8 ± 17.5    | 24.5 ± 18.1       | 45.3 ± 24.2     | 47.1 ± 34.7      | 18.7 ± 10.9    |
| Underclining_dbl. | 0              | 4.8 ± 2.6      | 6.6 ± 4.7         | 3.8 ± 2.0       | 10.9 ± 8.3       | 3.9 ± 2.8      |
|                   | 12             | 12.7 ± 6.9     | 10.8 ± 7.4        | 5.9 ± 3.2       | 19.6 ± 17.0      | 12.9 ± 9.8     |
| Underclining_one  | 0              | 9.3 ± 5.8      | 11.2 ± 7.3        | 7.2 ± 3.5       | 20.1 ± 18.4      | 6.8 ± 4.7      |
|                   | 12             | 33.1 ± 17.2    | 17.1 ± 11.8       | 14.7 ± 8.1      | 40.1 ± 33.6      | 26.1 ± 15.1    |
| Sidepull_IR_dbl.  | 0              | 7.1 ± 5.4      | 4.5 ± 3.9         | 16.5 ± 12.5     | 17.2 ± 19.8      | 6.4 ± 5.5      |
|                   | 12             | 12.5 ± 8.3     | 6.1 ± 4.8         | 24.8 ± 17.4     | 22.9 ± 22.2      | 9.2 ± 8.5      |
| Sidepull_IR_one   | 0              | 23.3 ± 13.1    | 8.7 ± 5.2         | 30.0 ± 21.9     | 25.3 ± 28.5      | 14.3 ± 8.8     |
|                   | 12             | 40.1 ± 19.3    | 19.1 ± 16.5       | 47.3 ± 29.1     | 42.2 ± 34.7      | 28.0 ± 13.3    |
| Sidepull_ER_dbl.  | 0              | 4.1 ± 2.0      | 7.3 ± 6.1         | 10.2 ± 9.0      | 11.5 ± 7.9       | 1.9 ± 1.0      |
|                   | 12             | 12.6 ± 5.9     | 16.0 ± 17.2       | 13.0 ± 9.6      | 21.7 ± 17.5      | 8.4 ± 5.5      |
| Sidepull_ER_one   | 0              | –              | –                 | –               | –                | –              |
|                   | 12             | –              | –                 | –               | –                | –              |

\( (F = 22.1, p < .001) \), MT \( (F = 11.9, p = .004) \) and LT \( (F = 18.4, p = .001) \). Interaction effects between arm positions and inclination angles could be observed for UT \( (F = 8.7, p = .002) \) and LT \( (F = 5.9, p = .006) \). The post-hoc pairwise comparisons among different arm positions at double-handed support however, only revealed significant differences for LT between Underclinging and Sidepull \( (p = .001) \), Underclinging and Sidepull_ER \( (p = .004) \) and Sidepull IR and Sidepull_ER \( (p = .001) \).

**Hand support and inclination.** The two-way repeated-measures ANOVA indicated significant main effects across hand support for BB \( (F = 26.3, p < .001) \); Underclinging: \( F = 38.0, p < .001 \); Sidepull_IR: \( F = 52.7, p < .001 \); SA \( (F = 17.4, p = .001) \); Underclinging: \( F = 11.0, p = .008 \); Sidepull_IR: \( F = 17.2, p = .001) \), UT \( (F = 35.9, p < .001) \); Underclinging: \( F = 60.6, p < .001 \); Sidepull_IR: \( F = 84.8, p < .001 \), MT \( (F = 29.0, p < .001) \); Underclinging: \( F = 15.9, p = .002 \); Sidepull_IR: \( F = 14.1, p = .002 \) and LT \( (F = 46.2, p < .001 \); Underclinging: \( F = 39.3, p < .001 \); Sidepull_IR: \( F = 21.3, p < .001 \) and significant main effects across inclination angle for BB \( (F = 21.4, p < .001 \); Underclinging: \( F = 38.0, p < .001 \); Sidepull_IR: \( F = 50.0, p < .001 \), SA \( (F = 15.7, p = .002 \); Underclinging: \( F = 17.0, p = .002 \); Sidepull_IR: \( F = 6.2, p = .028 \), UT \( (F = 32.8, p < .001 \); Underclinging: \( F = 30.5, p < .001 \); Sidepull_IR: \( F = 38.9, p < .001 \), MT \( (F = 19.4, p = .001 \); Underclinging \( F = 19.5, p = .001 \); Sidepull_IR: \( F = 35.8, p < .001 \) and LT \( (F = 35.1, p < .001 \); Underclinging: \( F = 24.5, p < .001 \); Sidepull_IR: \( F = 35.9, p < .001 \). A significant interaction between hand support and inclination angle was found for BB \( (F = 19.1, p = .001 \); Underclinging: \( F = 16.7, p = .001 \); Sidepull_IR: \( F = 14.1, p = .002 \), SA \( (F = 16.1, p = .001 \); Sidepull_IR: \( F = 5.5, p = .037 \), UT \( (F = 22.5, p < .001 \); Underclinging: \( F = 55.0, p < .001 \); Sidepull_IR: \( F = 28.7, p < .001 \), MT \( (F = 12.1, p = .004 \); Underclinging: \( F = 19.3, p = .001 \); Sidepull_IR: \( F = 19.5, p < .001 \) and LT \( (F = 9.4, p = .009 \); Underclinging: \( F = 25.5, p < .001 \); Sidepull_IR: \( F = 5.3, p = .038 \). Results of post-hoc pairwise comparisons among hand support and inclination are shown in Figure 2 for every muscle and arm position.

**Discussion**

The purpose of this study was to quantify and compare the EMG activity during four different arm positions of a static therapeutic climbing exercise and to investigate the effect of hand support and inclination on muscle activity levels. To interpret the results, EMG activity levels between 0% and 20% MVIC were considered low muscle activation, 21% to 40% MVIC were considered moderate muscle activation, 41% to 60% MVIC were considered high muscle activation and greater than 60% MVIC were considered very high muscle activation. Moderate muscle activation is considered to be adequate for neuromuscular training and muscle strengthening in the initial phase of rehabilitation (Kibler, Sciascia, Uhl, Tambay, & Cunningham, 2008; Tucci et al., 2011). The activation levels obtained from this study are, in general, low to moderate, suggesting this exercise is probably best suited for the early phase of shoulder rehabilitation. The different arm positions just revealed few significant differences. All five muscles showed a significant...
increase in muscle activation when changing from double-handed to one-handed support phase at almost all arm positions and inclinations. Nearly all different exercise variations (arm position and hand support) revealed a significant increase in muscle activation due to inclination angle.

**Biceps brachii**

EMG activity of BB across the 14 exercise conditions varied from 4.1% to 40.1% MVIC. In early phases of the non-operative or postoperative rehabilitation of biceps related disorders like SLAP lesions, isometric strengthening in all planes of shoulder motion with low loads on the BB should be performed to support the healing tissue (Cools, Borms, et al., 2014; Wilk et al., 2005). The release of one hand produced a significant increase in muscle activation of BB. With increasing wall inclination, the EMG activity at one-handed support phase exceeded the recommended low activation levels and therefore cannot be recommended in early phases of rehabilitation of biceps related disorders.

**Serratus anterior**

The 14 different exercise conditions performed in this study could elicit EMG activity of SA ranging from
4.5% to 24.5% MVIC, indicating mainly low SA muscular activation. Patients with GH pathologies often present with insufficient activity of SA muscle leading to muscle imbalances which cause inadequate upward rotation and posterior tilt of the scapula during arm movements. Therefore, adequate muscular activation during rehabilitation exercises should be achieved to improve muscular coordination in order for the patients to be able to address the SA (Ludewig & Braman, 2011; Ludewig & Reynolds, 2009). Compared to typically applied isometric strengthening exercises, this static therapeutic climbing exercise didn’t produce sufficient muscle activation for strengthening the SA (Tucci et al., 2011).

Trapezius

Some GH pathologies require shoulder rehabilitation exercises that focus on increasing the muscular activation of LT and MT while at the same time generating low UT activation (Cools, Struyf, et al., 2014; Ellenbecker & Cools, 2010; Wilk et al., 2005). The activation levels of UT obtained in this study were generally low and the activation levels of LT and MT were generally moderate to high. Especially the Jug and Sidepull_IR arm position during one-handed support revealed these required activation profiles and therefore indicate, that these positions are optimal for restoring UT/MT and UT/LT force-couple ratios.

Muehlbauer et al. (2013) presented the only available study, which analysed the EMG activation during dynamic therapeutic climbing exercises for the shoulder girdle. The activation values for UT (7.8% to 17.2% MVIC), MT (33.9% to 74.2% MVIC) and LT (31.8% to 51.1% MVIC) obtained during dynamic exercises are similar to those revealed in the present study. Closed-chain isometric exercises are considered to be safe in early phases of rehabilitation because of their limited range of motion and the control of joint load (Kibler et al., 2008). In terms of exercise selection for the early rehabilitation stage of shoulder patients, the static therapeutic climbing exercise of the current study can therefore present a safer but similar effective exercise than the dynamic exercises presented in Muehlbauer et al. (2013).

Increased muscle activation when releasing one hand during a static climbing position has already been shown for the trunk and leg muscles (Grzybowski et al., 2014; Mally et al., 2013). In the current study, the release of one hand produced a significant increase in EMG activity in LT, MT and UT and therefore can be assumed as an appropriate way of altering muscle activation patterns. As the healthy participants of this study where not able to perform the Sidepull_ER in one-handed position without any compensational movements, this exercise is not recommended in one-handed execution.

Limitations

The results of our study were obtained by measuring EMG activation in adult and climbing unexperienced participants without pathology, in order to gain first insights into the effect of arm position and hand support. However, it is not yet known, whether patients revealing muscle injuries or coordinative deficits execute the exercise in a similar muscle activation pattern, and respond to variations in arm position and hand support similarly. Therefore, future research needs to investigate the therapeutic climbing exercise in a patient group.

Conclusion

The results of this study demonstrate that for healthy climbing unexperienced adults the performed static therapeutic climbing exercise elicit similar muscular activation levels as common isometric shoulder rehabilitation exercises (Tucci et al., 2011). The analysed static climbing exercise has the potential to fulfil the objectives of the early phases of rehabilitation in respect to adequate muscle activation of the different portions of the trapezius muscle. The variation of arm position and hand support seem to be appropriate possibilities to control the intensity during a static therapeutic climbing exercise, as well as increasing wall inclination. Especially the release of one hand can be an effective exercise variation to increase the muscle activation and therefore should be used with caution to avoid overloading. Further studies now need to compare respective patient groups, in order to understand, if muscular activation patterns can be reproduced by individuals with pathologies.

Disclosure statement

No potential conflict of interest was reported by the authors.

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