RELEASING ONE HAND DURING THERAPEUTIC CLIMBING EXERCISES AFFECTS THE ACTIVATION OF ARM AND SHOULDER MUSCLES IN HEALTHY INDIVIDUALS

Gerda Strutzenberger[1], Daniela Leitl[1], Martin Pühringer[1] and Hermann Schwameder[1]

Department of Sport Science and Kinesiology, University of Salzburg, Austria[1]

Therapeutic climbing currently has high popularity in treating glenohumeral instability. Therefore, the aim of this study was to quantify the muscular activation of the middle and upper trapezius (MT, UT) and serratus anterior (SA) of four quasi-static climbing positions (Jug, Undercling, Sidepull with external and with internal rotation) of 15 participants. Additionally, the effect of releasing one hand from the support handle on the muscular activation was analysed. The maximum in both handed conditions were 23% (MT), 9% (UP) and 7% (SA). Releasing one hand significantly increased the muscle activation level, which was especially evident for the Sidepull with external rotation (MT, SA) and internal rotation (UT). The analysed positions elicited similar muscular activation levels as common shoulder rehabilitation exercises in healthy participants.

KEY WORDS: rehabilitation, shoulder complex, muscle activation, climbing.

INTRODUCTION: In patients with GH pathologies such as impingement or glenohumeral instability, scapular stabilization is impaired. As such decreased muscular activation of the serratus anterior (SA), lower and middle trapezius (LT, MT) in combination with an increased activation of the upper trapezius (UT) was observed in this patient group (e.g. Ellenbecker & Cools, 2010; Ludewig & Braman, 2011; Struyf, Nijs, Baeyens, Mottram, & Meeusen, 2011). Activating the scapular muscles is therefore an essential component of shoulder rehabilitation protocols. In a therapeutic setting, therapeutic climbing has the potential to address these muscles in a controlled setting, and simultaneously train the muscle force, mobility and whole-body coordination (Buechter & Fechtelpeter, 2011; Grzybowski, Donath, & Wagner, 2014; Muehlbauer, Stuerchler, & Granacher, 2012). Due to its adventurous component, therapeutic climbing might be more exciting compared to other rehabilitation exercises and increase patient compliance, which explains its current popularity. Therefore, it is quite surprising that there is only limited scientific background with respect to its effects on the muscular system of the shoulder complex (Buechter & Fechtelpeter, 2011; Grzybowski et al., 2014), and how simple variations affect the muscle activation. In a therapeutic setting different arm positions and releasing one hand from the wall are possibly variations to target different muscle activation. Therefore, the aim of this study was firstly to quantify muscle activation of the MT, UT and SA during four different arm positions of a quasi-static therapeutic climbing exercise in healthy individuals. Secondly, it was hypothesized that releasing one hand from the climbing hold influences the muscular activity of the contralateral side. The results of this study might be a relevant tool for generating therapeutic climbing rehabilitation protocols.

METHODS: Data of surface EMG activity of the MT, UT and SA of 14 healthy, climbing unexperienced male participants (28.5 ± 8.1 years, 1.81 ± 0.07 m, 80.7 ± 9.4 kg) were collected at a vertical wall inclination with the Myon 2.0 system and the software proEMG (Oxford Metrics, Ltd., UK, 2000 Hz). Skin preparations and electrode placement were conducted according to SENIAM (www.seniam.org) recommendations. The four quasi-static positions a) Jug, b) Undercling (UC), c) Sidepull with internal rotation (SIR) and d) Sidepull with external rotation (SER) (Figure 1) were analyzed.

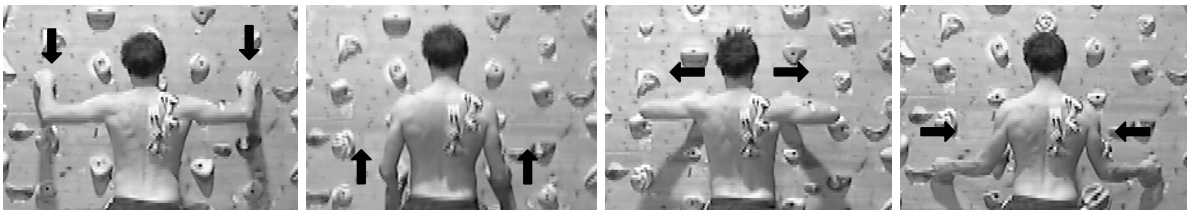

Figure 1. Four different arm positions: Jug (a), Undercling (b), Sidepull with internal rotation (c) and Sidepull with external rotation (d). Arrows indicating the loading direction on the climbing holds.

Following a standardized warm-up and measurements of the maximum voluntary isometric contraction (MVIC) the protocol for each position was following: 1. Take position with both hands on the climbing holds (double-handed) and hold for 5 seconds. 2. Release on command the left hand from the support-handle and hold for 5 seconds (single-handed). 3. Grab handle again and hold for 2 seconds. 4. Repeat until 3 valid trials are collected. The order of climbing position was randomized over all participants. Raw EMG was filtered (Butterworth, 10-300 Hz bandpass), rectified and smoothed using a 250 ms moving average window. For each phase (double/single) the first and last second were discarded and the mean value over the remaining 3 s was normalized to the MVIC data and used for further analysis. Statistics were calculated via SPSS 23. Criteria for normality were met (Shapiro Wilk test) and an ANOVA with repeated measurements and the factors position and handedness was calculated using $p=0.05$. For post-hoc testing, Bonferroni corrected t-tests were used. Muscle activation was quantified to be low: <20% MVIC, moderate: 21-40% MVIC, high: 41-60% MVIC and very high: >60% MVIC.

RESULTS: The middle trapezius demonstrates the highest activation with 9-17% (double handed) and 20-30% MVIC (single handed). The UP is with mean activation levels between 5-7% (double handed) and 9-21% MVIC (single handed) slightly more activated than the SA, which shows values between 1-6% (double handed) and 4-14% (single handed) (Figure 1). Participants were not able to adequately perform the SER position single handed, hence the SER position was not included in the ANOVA, resulting in corrected p-values of resulting in $p=0.017$ (handedness) and $p=0.006$ (position).

For the MT, SA and UT a significant main effect for handedness occurred ($p\leq0.006$). The UT additionally showed a significant position and interaction effect ($p<0.001$). In detail, releasing one hand led for all muscles in each position to significantly higher muscle activation with $p < 0.017$. The different arm positions revealed generally few differences, except for the UT for which the Jug revealed the lowest activation, followed by the Undercling and the Sidepull with internal rotation.

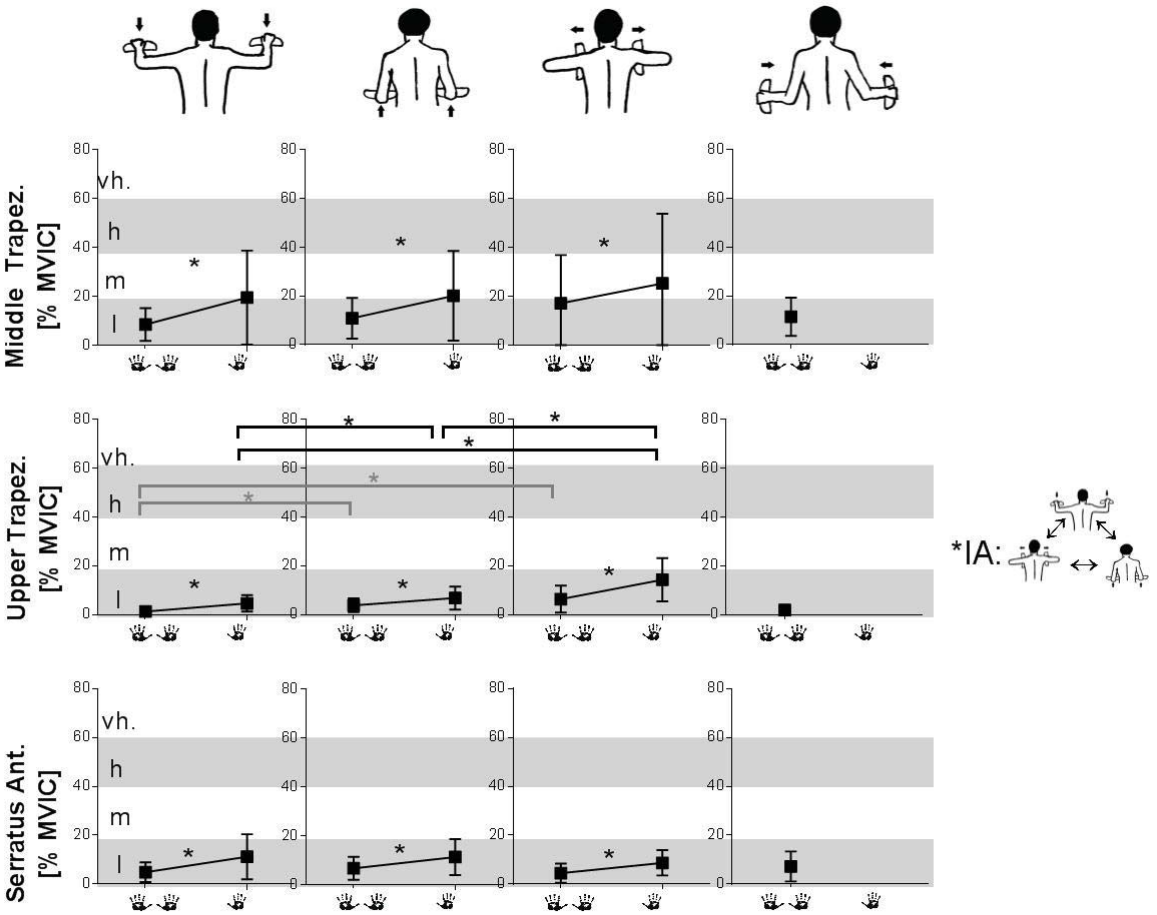

Figure 1: Mean EMG activity (% of MVC) at the different positions in single and double handed condition with activation zones (0-20%: l(ow), 21-40% m(edium), 41-60%: h(igh),>60% v(ery) h(igh)). IA: interaction effect between position and handedness.

DISCUSSION: Up to 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, Ciol, de Araujo, de Andrade, Martins, McQuade et al., 2011). The first aim of this research was to quantify the muscle activation generated by therapeutic climbing exercises. The muscle activation levels obtained from the healthy participants of this study are in general low, suggesting this exercise is probably best suited for the early phase of rehabilitation of scapular stabilization. At each position, the release of one hand led for all examined muscles to a significant increase, with the activation still being at a low activation level. Only for the MT releasing one hand, increased the mean MT muscle activation to a moderate level in all positions. As patients with GH diseases demonstrate muscular imbalances (e.g. decreased muscular activation of the SA, MT, increased activation of the UT), which cause e.g. inadequate upward rotation and tilt of the scapula during arm movements, the investigated quasi-static exercises could be adequate exercises for patients to learn to address these muscles in a controlled setting. Additionally the force balance of an increased MT activation in combination with a lower UT activation displayed by these exercises could be helpful in restoring optimal UT/LT force-couple ratios when the climbing position is adequately performed. Although the Sidepull with internal rotation produced moderate MT muscular activation, it should be used with caution. The GH internal rotation during this position may reduce the subacromial space and therefore increases the risk of impingement in patients with shoulder pathologies (Ellenbecker & Cools,

2010). The arm positions Jug, Undercling and Sidepull with an external rotation at GH should be preferred when performed double handed. As the healthy participants of this study where not able to perform the Sidepull with and external rotation in single handed position without any compensational movements, this exercise is not recommended in single handed execution. Limitation: The results of our study were obtained by measuring surface EMG activation in adult participants without pathology, in order to gain first insights in the effect of arm position and hand support. However, it is yet not 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 unexperienced adults the performed quasi-static therapeutic climbing exercises elicit similar muscular activation levels as common shoulder rehabilitation exercises. The analyzed quasi-static climbing positions have the potential to fulfil the objectives of the early phases of rehabilitation in respect to adequate muscle activation of the middle and upper part of the trapezius and serratus anterior muscle. The variation of arm position and hand support seem to be appropriate possibilities to control the intensity during a static therapeutic climbing exercise. The release of one hand can be an effective movement variation to increase the muscle activation. Further studies need to compare respective patient groups, in order to understand, if muscular activation patterns can be reproduced by individuals with pathologies.

REFERENCES:

Buechter, R. B., & Fechtelpeter, D. (2011). Climbing for preventing and treating health problems: a systematic review of randomized controlled trials. *Ger Med Sci, 9*, Doc19. doi: 10.3205/000142

Ellenbecker, T. S., & Cools, A. (2010). Rehabilitation of shoulder impingement syndrome and rotator cuff injuries: an evidence-based review. *Br J Sports Med, 44*(5), 319-327. doi: 10.1136/bjsm.2009.058875

Grzybowski, C., Donath, L., & Wagner, H. (2014). [Association between trunk muscle activation and wall inclination during various static climbing positions: implications for therapeutic climbing]. *Sportverletz Sportschaden, 28*(2), 75-84. doi: 10.1055/s-0034-1366552

Kibler, W. B., Sciascia, A. D., Uhl, T. L., Tambay, N., & Cunningham, T. (2008). Electromyographic analysis of specific exercises for scapular control in early phases of shoulder rehabilitation. *Am J Sports Med, 36*(9), 1789-1798. doi: 10.1177/0363546508316281

Ludewig, P. M., & Braman, J. P. (2011). Shoulder impingement: biomechanical considerations in rehabilitation. *Man Ther, 16*(1), 33-39. doi: 10.1016/j.math.2010.08.004

Muehlbauer, T., Stuerchler, M., & Granacher, U. (2012). Effects of climbing on core strength and mobility in adults. *Int J Sports Med, 33*(6), 445-451. doi: 10.1055/s-0031-1301312

Struyf, F., Nijs, J., Baeyens, J. P., Mottram, S., & Meeusen, R. (2011). Scapular positioning and movement in unimpaired shoulders, shoulder impingement syndrome, and glenohumeral instability. *Scand J Med Sci Sports, 21*(3), 352-358. doi: 10.1111/j.1600-0838.2010.01274.x

Tucci, H. T., Ciol, M. A., de Araujo, R. C., de Andrade, R., Martins, J., McQuade, K. J., et al. (2011). Activation of selected shoulder muscles during unilateral wall and bench press tasks under submaximal isometric effort. *J Orthop Sports Phys Ther, 41*(7), 520-525. doi: 10.2519/jospt.2011.3418