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# Modifying the shoulder joint position during shrugging and retraction exercises alters the activation of the medial scapular muscles

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ABSTRACT

*Background:* In patients with shoulder or neck pain, often an imbalance of the activation in the scapular upward and downward rotators is present which can cause abnormalities in coordinated scapular rotation. Shrug exercises are often recommended to activate muscles that produce upward rotation, but little information is available on the activity of the downward rotators during shrugging exercises. The position used for the shrug exercise may affect the relative participation of the medial scapular rotators.
*Objectives:* To compare muscle activity, using both surface and fine-wire electrodes, of the medial scapular muscles during different shoulder joint positions while performing shrug and retraction exercises.
*Design:* Controlled laboratory study.
*Method:* Twenty-six subjects performed 3 different exercises: shrug with the arms at the side while holding a weight ("Shrug"), shrug with arms overhead and retraction with arms overhead. EMG data with surface and fine wire electrodes was collected from the Upper Trapezius (UT), Levator Scapulae (LS), Middle Trapezius (MT), Rhomboid Major (RM) and Lower Trapezius (LT).
*Results:* The results showed that activity levels of the main medial scapular muscles depend upon the specific shoulder joint position when performing shrug and retraction exercises. High UT activity was found across all exercises, with no significant differences in UT activity between the exercises. The LS and RM activity was significantly lower during "ShrugOverhead" and the RM, MT and LT activity was significantly higher during "RetractionOverhead".
*Conclusions:* This study has identified that all three exercises elicited similar UT activity. LS and RM activity is decreased with the "ShrugOverhead" exercise. The "RetractionOverhead" was the most effective exercise in activating the medial scapular muscles.

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## 1. Introduction

The position and motion of the scapula is crucial for normal functioning of the shoulder and neck region (Kibler and McMullen, 2003). Patterned scapular muscle activations are necessary to place the scapula in an optimal position. The Upper Trapezius (UT) moves the scapula into upward rotation and elevation, the function of the Middle Trapezius (MT) is to retract the scapula and the Lower Trapezius (LT) causes upward rotation and depression of the scapula. In addition, the inferomedial directed fibres of the LT may also contribute to posterior tilt and external rotation of the scapula during humeral elevation. The Serratus Anterior is able to protract the scapula and to work with the UT and LT to upwardly rotate the scapula. The Levator Scapulae (LS) is believed to elevate the scapula and to work together with the Rhomboid Major (RM) to retract and rotate the scapula downwards (Escamilla et al., 2009; Castelein et al., 2015). Scapular dyskinesis (known as alterations in static scapular position and loss of dynamic control of scapular motion) and alterations in scapular muscle activation patterns are commonly found in association with shoulder and neck pain conditions (Szeto et al., 2002; Ludewig and Reynolds, 2009; Helgadottir et al., 2010; Kibler and Sciascia, 2010; Helgadottir et al., 2011; Kibler et al., 2012).

Patients with shoulder or neck pain often present with muscle imbalances between the upward rotators (UT and SA) and the

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downward rotators (LS and RM) of the scapula (Ludewig and Cook, 2000; Sahrmann, 2002; Cools et al., 2004; Ludewig and Reynolds, 2009; Struyf et al., 2014). These changes in muscular balance among the scapular rotators can cause abnormalities in coordinated scapular rotation (Sahrmann, 2002; Cools et al., 2003). Therefore, it is important to integrate exercises in the scapular rehabilitation program that target activation of the scapular muscles, with a focus on the activation of upward rotators while minimizing the activation of the scapular downward rotators (Sahrmann, 2002).

Often the “Shrug”-exercise has been prescribed in scapular rehabilitation programs to facilitate upward rotation of the scapula (Hintermeister et al., 1998; Ekstrom et al., 2003; Pizzari et al., 2014). This exercise is mainly performed in order to correct the drooping shoulder at rest, and during the early stages of elevation. However, Sahrmann (2002) did not find the “Shrug” optimal to emphasize the UT activity and the upward rotation as the “Shrug” was suggested to reinforce the activity of the RM and LS, contributing to the dominance of these scapular downward rotator muscles. Also other authors described that the “Shrug” with the arms by the side may activate the LS rather than UT (Moseley et al., 1992; Smith et al., 2004). So, in order to elicit improved balance among the upward and downward rotators, it may be desirable to modify a shrug exercise. Sahrmann (2002) advises that the “Shrug” should be performed with arms overhead so that the scapula is in upward rotation (“ShrugOverhead”). However, to date, no specific EMG research of the medial scapular muscles has been performed to confirm or reject the hypothesis of Sahrmann (2002) and consequently no evidence exists in order to support these recommendations.

Some studies have investigated EMG activity of scapular muscles during shrug exercises (Moseley et al., 1992; Choi et al., 2015; Pizzari et al., 2014). One study by Moseley et al. (1992) showed that the Shrug was an optimal exercise for the LS (muscle activity >50%MMT). A limitation of the study was that no statistical investigations were made to compare EMG activity between muscles or exercises. Pizzari et al. (2014) investigated the influence of starting a shrug in 30° of glenohumeral abduction (component of slight upward rotation) rather than with the arm by the side, and found that it generated greater Trapezius muscle activity in comparison with the shrug with the arms at the side. The muscle activity of the downward rotators however, such as LS and RM was not investigated in that study. Choi et al. (2015) investigated the EMG activity of the UT, LT and LS with surface electrodes during shrug exercises with different starting positions of shoulder abduction (30°–90°–150°) in patients with downward rotation positioning of the scapula. While LS muscle activity showed no significant differences, the muscle activity of the scapular upward rotators (UT, LT, and SA) did show significant differences among the shoulder abduction angles during shrug exercises. A limitation of this study was that LS activity was measured with surface EMG electrodes and that possible cross talk could have occurred between the UT and LS. In addition, this study did not investigate RM and MT EMG activity. Overall, there is a lack of research evaluating the activity of the downward rotators, namely the RM and LS during different shoulder joint positions of shrugging and retraction exercises. The main reason for the lack of information on the EMG activity of those muscles may be that they are located too deep to be investigated by surface EMG electrodes (Rudroff, 2008).

Therefore, the purpose of this study was to compare muscle activation levels, using both surface and fine-wire electrodes, of the medial scapular rotators (UT, MT, LT, RM, LS) during 1) the shrug exercise (=shrug with the arms at the side and with a weight), 2) the shrug exercise when arms are elevated, and 3) a retraction exercise while arms are elevated. Understanding variations in the recruitment of all medial scapular muscles (including the downward rotators) during shrug and retraction exercises and the influence of different starting positions may help guide clinicians to select the appropriate exercises for each patient.

## 2. Materials and methods

### 2.1. Subjects

Twenty-six subjects (15 female, 11 male, mean age 33.3 ± 12.3 years, ranging from 21 to 56 years old, mean height: 174.7 ± 7.8 cm, mean weight: 67.5 ± 8.9 kg) participated in this study. All subjects were free from current or past shoulder or neck pain and demonstrated full pain-free range of motion of both shoulders. They did not perform overhead sports nor upper limb strength training for more than 6 h/week. Twenty-two subjects were right-handed and 4 were left-handed. Written informed consent was obtained from all participants. The study was approved by the ethics committee of X.

### 2.2. General design

EMG data was collected from 5 scapulothoracic muscles (UT, MT, LT, LS, RM) on the dominant side of each subject during the performance of the shrug exercise, the shrug exercise started from an overhead position of the arms, and retraction exercise started from an overhead position of the arms.

### 2.3. Test procedure

The experimental session began with a short warm-up procedure with multidirectional shoulder movements, followed by the performance of the maximum voluntary isometric contractions (MVIC) of the muscles of interest. This data is needed for normalization of the EMG signals.

A set of 4 MVIC test positions was completed to allow normalization of the EMG data (Castelein et al., 2015). These consisted of the following:

1. “Abduction 90°” (sitting)
2. “Horizontal Abduction with external rotation” (prone lying)
3. “Arm raised above head in line with LT muscle fibers” (prone lying)
4. “Shoulder flexion 135°” (sitting)

Each MVIC test position was performed 3 times (each of the 3 contractions lasted for 5 s-controlled by a metronome) with at least 30 s rest between the different repetitions. The order of tests was randomized and there was a rest period of at least 1.5 min between the different test positions. Manual pressure was always applied by the same investigator and strong and consistent encouragement from the investigator was given during each MVIC to promote maximal effort. Before data collection, MVIC test positions were taught to each subject by the same investigator. When the participants were able to perform the proper movement pattern and timing of the exercise, EMG data was collected from the MVICs.

In the second part of the investigation, the subject performed three exercises. Fig. 1 shows the description of the different exercises. The exercises were performed randomly (simple randomization: envelopes containing the name of each exercise were shuffled for each participant and this sequence of exercises was allocated to that participant). Before data collection, the subject was given a visual demonstration of each exercise by the investigator. Each exercise consisted of a concentric phase of 3s and an eccentric phase of 3s. A metronome was used to control and

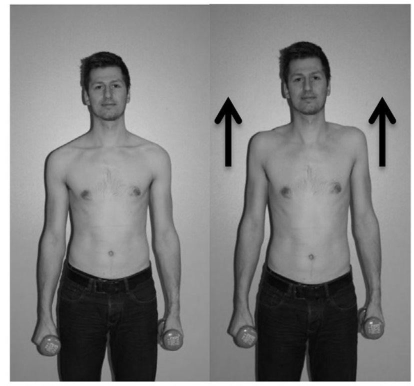
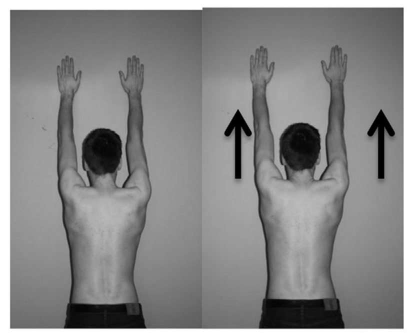
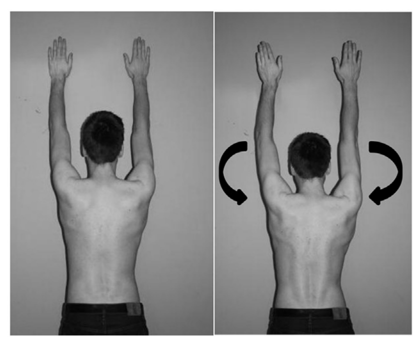
| | | |
|---|---|---|
| Shrug | Subject standing, holding the dumbbells (5kg) at the side, and elevating the shoulders and returning back to the starting position. (3s elevation – 3s depression). |  |
| ShrugOverhead | Subject standing, placing the arm in overhead position against the wall and performing a shrug movement and returning back to the starting position (3s elevation – 3s depression). (distance to the wall was determined as follow: subjects stood in front of the wall (facing the wall) with the arms besides the body, elbows flexed in 90°, elbow, wrist and fingers in neutral position. The distance to the wall was appropriate when the tips of the fingers were in contact with the wall) |  |
| RetractionOverhead | Subject standing, placing the arm in overhead position against the wall and performing an arm lift (retraction) movement and returning back to the starting position (3s retraction – 3s return). (distance to the wall is the same as noted in "ShrugOverhead") |  |

**Fig. 1.** Description of the exercises.

standardize the velocity speed of the movement (60 beeps/min). When the participants were able to perform the proper movement pattern and timing of the exercise, EMG data was collected from 5 repetitions of each exercise with 5s of rest in between each repetition. Between each exercise set, a break of 1.5 min was provided.

### *2.4. Instrumentation*

A TeleMyo 2400 G2 Telemetry System (Noraxon Inc., Scottsdale, AZ) was used to collect the EMG data. This study used a combination of surface and intramuscular electrodes. Bipolar surface electrodes (Blue Sensor, Medicotest, Ballerup, Denmark) were placed with a 1 cm interelectrode distance over the UT, LT and MT, according to the to the SENIAM (Surface Electromyography for the Non-Invasive Assessment of Muscles) Project Recommendations (Hermens et al., 2000; Cools et al., 2007; De Mey et al., 2009; Maenhout et al., 2010). A reference electrode was placed over the spinous process of C7 vertebrae. Before surface electrode application, the skin surface was shaved, cleaned and scrubbed with alcohol to reduce impedance (<10 kOhm). Intramuscular fine-wire electrodes was used to measure the EMG activity of the LS and RM. The paired hook fine-wire electrodes (Carefusion Middleton, WI, USA – wire length 5″ 125 mm) were inserted into the muscle belly (according to the locations described by Perotto et al., 2005) using a single-use 25-gauge hypodermic needle. This was done using real-time ultrasound guidance, which has been shown to be an accurate and repeatable method of intramuscular electrode placement. The surface and intramuscular electrodes were looped and taped on the skin to prevent them from being accidentally removed during the experiment and to minimize movement artifacts. The sampling rate was 3000 Hz. The device had a common mode rejection ratio of 100 dB. Gain was set at 1000 (baseline noise <1 μV root-mean-square (RMS)).

### *2.5. Signal processing and data analysis*

The Myoresearch 3.4 Master Edition Software Program was used for signal processing. The EMG signals were filtered with a high pass Butterworth filter of 20 Hz. Cardiac artifact reduction was performed, followed by rectification and smoothing (root mean square, window 100 ms) of the signals. The EMG data for each muscle and each participant was averaged for each exercise (6s: 3s

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concentric phase and 3s eccentric phase) across the 3 intermediate repetitions of the 5 repetitions completed. The first and fifth repetitions were not included in the analysis to control for distortion due to habituation or fatigue. These EMG data were normalized and expressed as a percentage of their MVIC. For each MVIC, the average EMG value was calculated over a window of the peak 2.5 s of the 5s. The average of the 3 trials was used for normalization. All MVIC test positions were analyzed for each muscle. The normalization value (100%) was the highest value for that muscle recorded during the MVIC tests.

### *2.6. Statistical analysis*

SPSS 22.0 was used for statistical analysis. Means ± standard deviations were calculated for the normalized EMG values (in % of MVIC) of the UT, MT, LT, LS & RM for each exercise.

Data was checked for differences between male and female subjects. Since there were no gender differences, there was no need for further comparisons. A linear mixed model was applied to determine if there were significant differences in EMG activity between different exercises and different muscles (two factors: "Exercise" and 'Muscle"). The residuals of the linear mixed models were checked for normal distribution. Post hoc pairwise comparisons were performed using a Bonferroni correction. An alpha level of 0.05 was applied to all the data in determining significant differences.

## 3. Results

The mean EMG activity of each scapular muscle during the different exercises is provided in Table 1.

A significant interaction effect for Exercise*Muscle was found ($p < 0.001$). Post-hoc tests revealed that for UT, there were no significant differences between the different exercises. The results revealed that both the MT ($p < 0.047$) and LT ($p < 0.001$) were significantly more activated during "RetractionOverhead" in comparison with "Shrug" and "ShrugOverhead". The LS generated significantly higher activity during "Shrug", in comparison with "RetractionOverhead" and "ShrugOverhead" ($p < 0.001$). The RM generated the most activity during "RetractionOverhead" in comparison with "Shrug" ($p = 0.003$) and "ShrugOverhead" ($p < 0.001$).

When comparing different muscles' activity for each exercise, post-hoc tests revealed that during the "Shrug", the LS is significantly more activated than the UT ($p = 0.021$), MT ($p < 0.001$), LT ($p < 0.001$) and RM ($p < 0.001$). The activity of UT during "Shrug" was significantly higher than MT, LT and RM ($p < 0.001$); and the activity of RM during "Shrug" was significantly higher than MT and LT. During "ShrugOverhead", the UT generated significantly higher activity than the MT, LT and RM ($p < 0.001$). Also the LS activity was significantly higher than the MT ($p = 0.003$) and LT ($p = 0.004$) activity during the "ShrugOverhead". During "RetractionOverhead", the MT activity was significantly lower than the UT ($p = 0.002$), LS ($p = 0.032$) and RM ($p = 0.001$) activity.

**Table 1**
EMG Activity (%MVIC) of each scapular muscle during the different exercises.

| | Shrug | ShrugOverhead | RetractionOverhead |
|---|---|---|---|
| Upper Trapezius | 33.8 ± 12.9 | 25.8 ± 11.9 | 28.4 ± 12.5 |
| Middle Trapezius | 8.1 ± 5.3 | 6.9 ± 4.6 | 16.1 ± 11.6 |
| Lower Trapezius | 3.4 ± 1.9 | 7.2 ± 4.5 | 22.4 ± 8.2 |
| Levator Scapulae | 44.0 ± 25.8 | 19.1 ± 14.1 | 25.9 ± 22.7 |
| Rhomboid Major | 18.8 ± 15.0 | 10.3 ± 7.3 | 29.9 ± 15.7 |

## 4. Discussion

The aim of this study was to compare muscle activity levels, using both surface and fine-wire electrodes, of all medial scapular muscles (UT, MT, LT, RM & LS) during three exercises: (1) the shrug exercise with the arms at the side while holding a weight (="Shrug"), (2) the shrug exercise arms are elevated (="ShrugOverhead"), and (3) a retraction exercise while arms are elevated ("RetractionOverhead").

The major finding of this study is that activity levels of the main medial scapular muscles depend upon the specific shoulder joint position while performing the shrug and retraction exercises. This study demonstrates high activity of the UT across all exercises, and shows the lowest activity of the LS and RM during "ShrugOverhead" and the highest activity of the RM, MT and LT during "RetractionOverhead". This is the first study establishing specific scapular muscle activation patterns during these selected scapular exercises, in particular in the deep scapular muscles like RM and LS.

In the literature, the "Shrug" has been prescribed to strengthen the UT (Hintermeister et al., 1998; Ekstrom et al., 2003; Pizzari et al., 2014). In this study, although the numeric data suggest higher activity of UT during the basic shrug exercise, it was found that the amplitude of UT activation was not statistically different among the three different exercises (Shrug − ShrugOverhead − RetractionOverhead). As a consequence, this indicates the capability of all three exercises to activate the UT at a moderate level (between 25 and 33%MVC).

In contrast with the EMG results of the upward rotator (UT), the EMG activity of the downward rotators (LS and RM) does show differences between the exercises. The LS activity during the "ShrugOverhead" (19.1 ± 14.1%MVC) and the "RetractionOverhead" (25.9 ± 22.7%MVC) is significantly lower ($p < 0.001$) in comparison with the "Shrug" (44.0 ± 25.8%MVC). Moreover, the "Shrug" is the only exercise in which the activity of the LS is significantly higher than all other investigated muscles, including the UT ($p = 0.021$). In addition, the RM also shows the lowest activity during the "ShrugOverhead". So the results of the current study provide evidence of the hypothesis of Sahrmann (2002) that the "ShrugOverhead" should be preferred over the "Shrug", when the purpose of the exercise is to promote UT activity, with minimal activity in LS and RM. This means that this overhead positions enhances the function of UT to elevate the scapula and to rotate the scapula upwards, as it decreases the activity of LS and RM, that work together to rotate the scapula downwards. This is in line with the suggestions of several other authors to adapt the "Shrug" exercise, with a position of more upward rotation of the scapula in order to minimize the activation of the scapular downward rotators (that are expected to work during the "Shrug") and enhance the scapular upward rotators (Sahrmann, 2002; Choi et al., 2015; Pizzari et al., 2014). Using anatomical principles, it seems reasonable that if the scapula changes into more upward rotation (in case of "ShrugOverhead"), the line of pull of different muscles changes which causes changes in the length–tension relationships of the muscles assessed. Choi et al. (2015) also investigated LS activity with surface EMG electrodes in shrug exercises with different shoulder abduction angles (30°–90°–150°) in patients with downward rotation positioning of the scapula. In contrast with our results, they did not find significant differences in LS muscle activity among the shoulder abduction angles during the shrug exercises. However, the balance of UT/LS muscle activity ratio was significantly greater at higher shoulder abduction degrees (90° in comparison with 30°), indicating a relatively higher activation of the UT compared to the LS.

The "RetractionOverhead" resulted in the highest activation (ranging from 16 to 30%MVC) of all medial scapular muscles (RM, MT and LT) in comparison with the other exercises, indicating that this exercise is decent for the general activation of the posterior

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medial scapular shoulder musculature. The MT activity was significantly more activated during a retraction movement ("Retraction 180°") in comparison with an upward rotation movement ("Shrug" and "Shrug180°"), which is in line with the known muscle function of the MT, a retractor of the scapula. Remarkably, in this study, the activity of the MT was significantly lower than that of the UT, LS and RM during "RetractionOverhead". The finding that LS and RM work during "RetractionOverhead" is logical as these muscles work together to retract the scapula. It could be that the other muscles (other than the MT) assist during retraction of the scapula due to the more upward rotation of the scapula in an overhead position.

Regarding the LT, it is clinically believed that this muscle has an essential component during upward rotation of the scapula. The LT makes up the crucial lower force couple responsible for control against scapular elevation produced by the LS & UT. A low amount of LT activity was seen during "Shrug" (3.4 ± 1.9%MVC) and "ShrugOverhead" (7.2 ± 4.5%MVC). The exercise "RetractionOverhead" was effective in activating the LT to its highest (22.4 ± 8.2% MVC). The low LT activity during Shrug has also been found in the study from Pizzari et al. (2014) (2002) (3.5 ± 18.4%MVC). Although the "ShrugOverhead" and "RetractionOverhead" have the same starting position, i.e. with the arms elevated which causes an upward rotation of the scapula, the LT is more activated when performing retraction in comparison with when performing shrug. So, besides the role of LT as a muscle that controls the movement of the scapula (Ballantyne et al., 1993), it seems that in an overhead position the fibres of the LT are ideally placed to pull the scapula in retraction. Other studies did also describe maximum activity of the LT when resistance is applied to the arm when raised above the head in line with the LT (in prone position) (Ekstrom et al., 2003).

Interpretation of the results must be viewed within the limitations of the study. It is a limitation that the shrug exercise was performed with weight, while the other exercises were performed without weight. However, this decision was made as these conditions come closest to the way these exercises are performed in clinical practice. This study investigated five muscles using two different kinds of electrodes: surface and fine wire electrodes. EMG activity of the superficial muscles (UT, MT, LT) was investigated with surface electrodes. The fine wire electrodes allowed assessment of the EMG activity of the deeper lying muscles (LS and RM), which is difficult using surface electrodes due to the cross talk from superficial muscle layers. In view of this fact, caution should be taken when comparing the results among the different muscles activity (surface versus fine-wire). It is still under debate whether surface and fine wire electrodes measure the same kind of muscle activity (Giroux and Lamontagne, 1990; Bogey et al., 2000; Jaggi et al., 2009; Waite et al., 2010; Johnson et al., 2011). Nevertheless, other studies have also compared surface EMG results with fine-wire EMG results in the shoulder region (Boettcher et al., 2010; Wickham et al., 2010; Wattanaprakornkul et al., 2011). In this study, the amplifier's bandwidth was wide enough for both intramuscular and surface electrode signals ensuring that the data from the intramuscular electrodes could be accurately compared to that of the surface electrodes once both had been normalized (Wickham et al., 2010).

While this study provided useful information regarding the muscles being activated during various exercises, they did not document the associated scapular kinematics (3D analysis). Investigating scapular movements, along with muscle activity during exercises, would provide additional information clinicians can use to select exercises based on the needs of the subjects. As this study has been performed on healthy individuals, caution needs to be taken when applying the results of this study to patients. However, the majority of electromyography research on which clinicians currently base rehabilitation programs is from studies of asymptomatic subjects. Clearly, future investigations targeting symptomatic persons performing scapular exercises would advance our understanding of the symptomatic shoulder or neck and potentially facilitate refinement of our rehabilitation programs.

## 5. Conclusion

The exercises Shrug, ShrugOverhead and RetractionOverhead showed varying activity of both superficial and deeper lying medial scapular muscles. This study has identified that all three exercises elicited similar UT activity. The lowest LS and RM activity is best achieved with the "ShrugOverhead" exercise. The "RetractionOverhead" was the most effective exercise in activating the medial scapular muscles. These findings provide insights into scapular muscle activation patterns during exercises that involve the medial scapular muscles, in particular in the deep scapular muscles RM and LS.

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