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Original article

Serratus anterior or pectoralis minor: Which muscle has the upper hand during protraction exercises?

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ABSTRACT

Background: The Serratus Anterior (SA) has a critical role in stabilizing the scapula against the thorax. Research has linked shoulder and neck disorders to impairments in the SA activation. Exercises that target the SA are included in the rehabilitation of shoulder or neck pain and mostly include a protraction component. The Pectoralis Minor (PM) functions as a synergist of the SA. From the literature it is unclear to what extent PM is activated during SA exercises.
Objectives: To determine the activity of SA and PM during different protraction exercises.
Design: Controlled laboratory study.
Method: 26 subjects performed 3 exercises: Modified Push-Up Plus (Wall Version), Modified Knee Push-Up Plus (Floor version) and Serratus Punch. Electromyographic (EMG) data was collected from the SA (surface) and PM (fine-wire EMG).
Results: During the Serratus Punch the SA activity was significantly higher than the PM activity. During the Modified Push-Up Plus exercises (both Wall and Floor version), the SA and PM activity were comparable. The PM showed the highest activity during the Serratus Punch and the Modified Push-Up Plus (Floor), which was significantly higher than during the Modified Push-Up Plus (Wall). The SA showed the highest activity during the Serratus Punch, which was significantly higher than during the Modified Push-Up Plus (Floor) which was in turn significantly higher than the activity during the Modified Push-Up Plus (Wall).
Conclusions: All exercises activated the PM between 15 and 29% Maximum Voluntary Isometric Contraction and the SA between 15 and 43%. The Modified Push-Up Plus exercise against the wall and the floor activated the SA and PM to a similar degree. When maximum activation of the SA with minimal activation of the PM is desired in healthy subjects, the “Serratus punch” seems to be the optimal exercise.

1. Introduction

Among the muscles attached to the scapula, the Serratus Anterior (SA) muscle has a critical role in stabilizing the scapula against the thorax (Lear and Gross, 1998; Smith et al., 2003). Additionally, SA contributes to all components of the movement of the scapula during elevation of the arm: upward rotation, protraction and external rotation[1] (Lear and Gross, 1998). Research has linked shoulder and neck disorders to impairments in the activation of the SA muscle (weakness, fatigue, timing problems) (Glousman et al., 1988; Scovazzo et al., 1991; Wadsworth and Bullock-Saxton, 1997; Ludewig and Cook, 2000; Helgadottir et al., 2011; Sheard et al., 2012; Larsen et al., 2013). Therefore, various exercises that target the SA are included in the rehabilitation of patients with shoulder or neck pain (Moseley et al., 1992; Andersen et al., 2014; De Mey et al., 2014; Piraua et al., 2014).

Exercises that have been prescribed to predominantly activate the SA mostly include a protraction component. Push-Up exercises are known to be one of the most effective exercises for activating the SA. The Push-Up exercise is a closed kinetic chain exercise performed in a prone position by raising and lowering the body using the arms. Studies showed that the “plus-phase” of the Push-Up exercise shows the highest SA activation as compared with

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[1] Different authors cited in the article use different terminology for same movements: i.e. for scapular rotations: upward (lateral or external)/downward (medial or internal) rotation, anterior/posterior tilt and internal/external rotation. Protraction/retraction and elevation/depression are often described as movements of the clavicle (Helgadottir et al., 2010).

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other SA activation exercises (Decker et al., 1999; Ludewig et al., 2004). The "plus-phase" involves posterior translation of the thorax on relatively fixed scapulae, which can be done alone or along with push-ups (Hardwick et al., 2006). Ludewig et al. (2004) suggested that the SA was selectively activated to a greater extent in "Push-Up Plus" than in standard Push-Up exercises. Different modifications on the Push-Up Plus exercises are commonly used in clinical practice: Push-ups can be performed either on the floor ("Floor Push-Up Plus") or against the wall ("Wall Push-Up Plus"), supported on elbow ("Elbow Push-Up Plus"), or hands or feet or knee ("Knee Push-Up Plus"). Alternatively, the "Serratus Punch" (=performing protraction in open kinetic chain) is an exercise that is also often used to activate the SA (Escamilla et al., 2009; Liebenson, 2012).

The Pectoralis Minor (PM) functions as a synergist of the SA. Both the SA and the PM engage in the protraction movement of the scapula. From the literature it is unclear to what extent PM is activated during SA exercises. Apart from the protraction movement, the PM also causes, downward rotation, depression and anterior tilting of the scapula (Oatis, 2004). Overuse of this PM might result in adaptive shortening of the muscle. A shortened PM has been identified as a risk factor that contributes to abnormal scapular positioning (Tate et al., 2012). When PM lacks extensibility the scapula is anteriorly tilted and internally rotated (Borstad, 2008), which may lead to the development and perpetuation of upper limb symptoms (rounded shoulder posture, glenohumeral joint dysfunction, subacromial impingement) (Borstad, 2008; Lynch et al., 2010; Wong et al., 2010; Tate et al., 2012; Struyf et al., 2014). Clinical theories (Borstad and Ludewig, 2005; Ludewig and Reynolds, 2009; Cools et al., 2014b) suggest that motor strategy favoring activity in PM over SA is thought to be detrimental. So when performing exercises that include a protraction movement aiming to activate the SA, it is important to know the influence of that exercise on the activation of the PM.

Several studies have investigated SA activity during different SA exercises (Moseley et al., 1992; Decker et al., 1999; Ludewig et al., 2004; Maenhout et al., 2010; De Mey et al., 2014; Park et al., 2014; Piraua et al., 2014). However, to date, no study has investigated the PM activity when protraction exercises are performed nor compared SA and PM activity. One study of Moseley et al. (1992) investigated SA and PM activity during 2 protraction exercises: "Push-Up with hands apart" and "Push-Up with a Plus". They found these 2 exercises optimal (>50% maximum manual muscle strength test) for both SA and PM, but did not compare muscle activity between muscles or exercises. Moreover, they did not concentrate on the plus-phase, but on the whole exercise. Consequently, EMG investigations are necessary in order to address this current deficit in our knowledge regarding the muscle balance between the SA and PM during exercises that are thought to activate the SA.

Therefore, the purpose of this study was to investigate the EMG activity of the PM and the SA during 3 protraction exercises: (a) the "Modified Push-Up Plus" (Wall Version) (b) the "Modified Knee Push-Up Plus" (Floor Version) and (c) the "Serratus Punch".

2. Methods

2.1. Subjects

Twenty-six subjects (15 female, 11 male, mean age 33.3 ± 12.4, ranging from 21 to 56 years old, weight 67.1 ± 9.2 kg, height 174.2 ± 8.2 cm) participated in this study. The choice for the sample size was based on previous research in that area, that investigated differences in SA activity between exercises (Decker et al., 1999; Ludewig et al., 2004; Hardwick et al., 2006; De Mey et al., 2014; Park et al., 2014; Piraua et al., 2014) and that investigated both SA and PM activity (Moseley et al., 1992). Descriptive characteristics of the subject group can be found in Table 1. 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. Investigation of the in- and exclusion criteria was performed by a clinical expert with several years of experience. 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 the SA and the PM on the dominant side of each subject during the performance of the Modified Push-Up Plus (Wall Version), the Modified Knee Push-Up Plus (Floor version) and the Serratus Punch.

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. These data are needed for normalization of the EMG signals. A set of different isometric 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 Lower Trapezius (LT) muscle fibers" (prone lying)
4. "Shoulder flexion 135°" (sitting)
5. "Arm raised above head in line with PM muscle fibers" (supine lying)

All MVICs were performed prior to the exercises, except for the MVIC "Arm raised above head in line with PM muscle fibers". This MVIC was performed in supine lying and was always performed at the end (after the exercises) to avoid pressure on the electrodes of the dorsal muscles (due to their contact with the examination table because of the supine position) until all exercises were performed. Each MVIC test position was performed 3 times (each of the contractions lasted for 5 s-controlled by a metronome) with at least 30 s rest between the different repetitions. 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, and sufficient practice was allowed.

In the second part of the investigation, the subject performed 5 repetitions of 3 different exercises (Table 2). The exercises were performed randomly. Before data collection, the subject was given a visual demonstration of each exercise by the investigator. Each exercise consisted of a concentric protraction phase of 3 s and an

Table 1
Descriptive characteristics of the subjects.[a]

	Women	Men	Total
N	15	11	26
Age (years)	31.9 ± 12.8	35.3 ± 12.4	33.3 ± 12.4
Weight (kg)	62.7 ± 7.3	73.2 ± 7.6	67.1 ± 9.2
Height (cm)	169.2 ± 6.2	181.0 ± 4.6	174.2 ± 8.2

[a] Data reported as mean ± Standard deviation (SD).