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Electromyographic analysis of shoulder muscles during press-up variations and progressions

Lee Herrington *, Rosemary Waterman, Laura Smith

Directorate of Sport, Exercise and Physiotherapy, University of Salford, UK

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ABSTRACT

Due to the versatility of the press-up it is a popular upper extremity strengthening and rehabilitation exercise. Press-up programmes are often progressed by increasing weight-bearing load and using unstable bases of support. Despite the popularity of the press-up research examining press-up variations is limited. The aim of the study was to examine the influence of common press-up exercises on serratus anterior, infraspinatus, anterior deltoid, pectoralis major and latissimus dorsi muscles overall EMG activity. Twenty-one healthy individuals participated in this study. Surface electrodes were placed on pectoralis major, anterior deltoid, infraspinatus, serratus anterior and latissimus dorsi muscles. Participants were tested under 7 static press-up conditions that theoretically progressively increase weight-bearing load and proprioceptive challenge while surface electromyographic activity was recorded. There was a high correlation between increased weight-bearing load and increased EMG activity for all muscles in stable base conditions. The introduction of the unstable base conditions resulted in an activation decline in all muscles. Within the two-armed press-up the Swiss ball resulted in decreased activation in all muscles except pectoralis major. Serratus anterior demonstrated the greatest activation as a percentage of maximum isometric contraction across all exercises. The findings of this study indicate that by varying the weight-bearing load and base of support whilst in the press-up position results in significantly different demands on shoulder and scapula muscles.

1. Introduction

Optimal functioning and stability of the shoulder complex is reliant on scapulothoracic and glenohumeral stabilisation and humeral movement control (Lephart and Henry, 1996). Dysfunction of the scapulothoracic joint with altered scapula movement results in dyskinesis of the joint with associated abnormal glenohumeral motion (Ludewig and Cook, 2000). Abnormal shoulder motion has been linked to multiple shoulder pathologies and injury with shoulder pain being one of the most common musculoskeletal complaints (Lunden et al., 2010).

Within the upper extremity the acromioclavicular, sternocalvicular, glenohumeral and scapulothoracic joints are described as a kinetic chain (Lephart and Henry, 1996). Closed kinetic chain (CKC) activities with the distal segment fixed as motions occur proximally are advocated exercises for the upper extremity (Lear and Gross, 1998). The use of CKC exercises with progressive loading and proprioceptive (stability) challenges has become accepted practise during shoulder and scapula rehabilitation programmes (Pontillo et al., 2007). The press-up is a common upper extremity CKC rehabilitation and strength training exercise (Gouvali and Boudolos, 2005). Popularity of the exercise can be explained by the versatility of the press-up with variations including the wall, kneeling and box press-up. Within each variation there is the opportunity to add further changes that accommodate increased loading and stability challenges. Research suggests that the press-up exercise has not only resulted in muscular strength gain but also improvements in proprioception and neuromuscular control, promotion of co-activation of stabilising muscles, reduction in shear forces and equal joint compression distribution (Tucker et al., 2008; Lephart and Henry, 1996).

A common progression from the box press-up to the standard press-up is used in strengthening and rehabilitation programmes (Sandhu et al., 2008). Decker et al. (1999) and Ludewig et al. (2004) reported significantly higher serratus anterior activity in the standard press-up 'plus' when compared to the box press-up 'plus', the 'plus' representing movement of the scapula into full protraction.

* Corresponding author at: Directorate of Exercise, Sport and Physiotherapy, Allerton Building, University of Salford, Salford, Greater Manchester M6 6PU, UK. Tel.: +44 161 295 2326.

E-mail address: l.c.herrington@salford.ac.uk (L. Herrington).

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Much research has focussed on the use of the 'plus' phase due to the proposed low upper trapezius/high serratus anterior ratio the motion elicits (Ludewig et al., 2004; Lunden et al., 2010). Ludewig et al. (2004) reported the 'plus' phase of the press-up has shown serratus anterior activity to reach 120% versus 80% of maximal isometric voluntary contraction (MIVC) for the press-up and upper trapezius to be 20% in the push up and only 9% in the 'plus' phase (Ludewig et al., 2004). However caution in using the 'plus' phase in the press-up should be considered until further research into the scapula kinematics has been undertaken, as although it creates the desired increase in muscle activity it may not create appropriate muscle co-activation patterns (Ludewig and Cook, 2000). Lunden et al. (2010) examined the kinematics of the 'plus' phase which involves active scapula protraction at the top position of the press-up and noted that during the 'plus' phase the scapula exhibited increased internal rotation and decreased upward rotation with a possible decrease in subacromial space with the concomitant risk of subacromial impingement.

Previous research reporting on progressions from the box to the standard press-up which recorded activity from other muscles such as pectoralis major, infraspinatus and anterior deltoid, reported significantly greater muscle activity in all three muscles during the standard press-up compared to the box press-up (Uhl et al., 2003). The increase in muscle activity between the box and standard press-up may be as a result of increased forces through the shoulder as the centre of mass moves further away from the distal base of support (knees and feet) in the standard press-up (Suprak et al., 2011).

In order to explore progressions within the box and standard press-up a limited number of authors have researched the effect of progressing from bilateral support (two-armed) to unilateral support (one-armed) and found muscle activity increases in the one-armed press-up. Maenhout et al. (2010) reported serratus anterior activity to be significantly higher in the one-armed box press-up 'plus' (36.7% of maximum isometric contraction (MIVC) compared to the two-armed box press-up 'plus' (25.3%). No research has been found that explores progressions from two-armed to one-armed within the standard press-up without the 'plus' phase. Uhl et al. (2003), studied the press-up without the 'plus' phase for pectoralis major, anterior deltoid and infraspinatus EMG activity from bilateral to unilateral weight bearing. The authors reported significantly greater muscle activation occurred in the unilateral press-up for all muscles (Uhl et al., 2003).

Unstable surfaces are often used during rehabilitation in an attempt to improve proprioception and increase muscle activation. The reported changes in muscle activation have been conflicting. Lehman et al. (2008) examined muscle activation during the press-up on a Swiss ball compared to a stable base, pectoralis major and serratus anterior showed no significant differences in activity; Pontillo et al. (2007) reported significantly less serratus anterior activity during the box press-up on an unstable platform when compared to a stable platform. Pontillo et al. (2007) measured activity on a force platform in the static press-up position held for 20 s each time without randomly allocating the exercises. The authors suggested that muscle fatigue could have had an effect on the serratus anterior explaining the decrease in activation.

Sandhu et al. (2008) also reported significantly greater pectoralis major activation with the addition of the Swiss ball during the standard press-up, which is in contrast to Lehman et al. (2006). It is of note that Lehman et al. (2006) used subjects who routinely participated in strength training while Sandhu et al. (2008) used subjects with little strength training experience. Level of training could produce significantly different results due to neuromuscular adaptation.

Evidence supporting the use of press-up progressions as an appropriate rehabilitation exercise for the shoulder is limited. Authors have investigated a variety of press-up variations examining loading and stability progressions (Ekstrom et al., 2005; Lehman et al., 2006; Sandhu et al., 2008). However, none have researched rehabilitation progressions within the box press-up and standard press-up that has included progressive loading and stability challenges. Research has focused on individual aspects such as stability or loading without assessing the muscular activity within and between each aspect. Of the limited studies that have researched progressions few have speculated on where in the rehabilitation process these variations should be included.

The aim of this study is to explore isometric press-up variations and examine surface EMG (sEMG) activity within and between each exercise variations. The over-arching hypothesis of the study being that there will be greater muscle EMG activity as the nature of the exercise is changed, as loading is increased and stability decreased through the shoulder during press-up progressions it is expected EMG activity will increase.

2. Method

2.1. Participants

21 healthy, physically active subjects volunteered to participate (10 male and 11 females with a mean age of 22.8 (±1.4) years). The study was approved by the University ethics committee and all subjects gave written informed consent. All participants had no history of neck, shoulder, elbow wrist or hand injury/surgery within the previous six months.

2.2. Procedures

Testing was done using a KinePro Wireless EMG using KinePro EMG Triode Electrodes (Nickle-Plated Brass) with a 1 cm inter-electrode distance. KinePro V.3.2 software was used for signal processing. Surface EMG (sEMG) was high and low pass filtered between 10 and 500 Hz, preamplified ($\times$1000), and A/D converted at a rate of 1562 Hz using the KinePro wireless EMG system (Kine EHF, Reykjavík, Iceland). To determine the sEMG signal on/off, a computer aided algorithm was used to allow a threshold value to be calculated from 2 standard deviations above baseline, each trace was also visually inspected (Hodges and Bui, 1996). To quantify the sEMG amplitude, root mean square (RMS) was calculated, epochs were taken at 20 ms intervals and a mean value calculated for a standardised period (from onset for 9 s).

Participants were tested on their dominant side; the hand they wrote with. Electrodes were placed over selected muscles. Sites for electrode placement was prepared by shaving the area (where necessary), the skin exfoliated using Nuprep™ gel and swabbed with Cutisoft® wipes to ensure optimal electrode attachment and reduce skin impedance. Electrodes were placed in alignment with direction of muscle fibres.

2.2.1. Electrode placement position

Pectoralis major: 4–5 cm below the clavicle, medial to the anterior axillary border (Lehman et al., 2006). *Anterior Deltoid:* 4–5 cm inferior to acromion process (Pontillo et al., 2007). *Infraspinatus:* Mid distance between the scapula spine and inferior angle of scapula, 2 cm lateral from scapula medial border (Pontillo et al., 2007). *Serratus Anterior:* lower fibres of serratus anterior on the mid axillary line at rib level 6–8 with shoulder flexed at 90° (Ekstrom et al., 2005). *Latissimus dorsi:* 5 cm distal to the inferior angle of the scapula parallel to the lateral border of the scapula (Lehman et al., 2006).