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EXERCISE PHYSIOLOGY

The impact of load and base of support on electromyographic onset in the shoulder muscle during push-up exercises

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Summary *Objective:* To investigate the effects of base of support (BOS) and external loads on electromyographic (EMG) onset in the shoulder muscles during push-up exercises.
Methods: Two levels of external load were applied at two levels of BOS stability during push-up exercises. EMG onset in six shoulder muscles was measured in 30 healthy participants.
Results: With load set at 4% of body weight (BW), EMG onset in the lower trapezius (LT) ($P = 0.003$) and biceps brachia (BB) ($P = 0.001$) was significantly decreased with no load. Conversely, in other muscles (the upper trapezius (UT), teres major (TM), seratus anterior (SA) and deltoid posterior (DP)), time to EMG onset did not change significantly. No significant changes in EMG onset were observed with load at 2% of BW. The average time to EMG onset was significantly decreased for different stages of BOS instability in the LT ($P = 0.04$) and UT ($P = 0.001$).
Conclusion: Both load and BOS instability reduce time to EMG onset, but BOS instability produces greater reductions.

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Introduction

Due to its relative lack of bony constraints, the shoulder has the largest range of motion of any joint in the human body (Brox, 2003; Lunden et al., 2010), allowing positioning of the hand in many functional positions (Veeger and van der Helm, 2007). A fine balance between mobility and stability is required to sustain the optimal function of the shoulder joint (Horlings et al., 2009). During dynamic shoulder exercises there is an interaction between physiological and biomechanical factors, including changes in the moment arm of force and gravity and muscle length, and the position of the joint contact surfaces at different joint angles (Veeger and van der Helm, 2007). During static exercises these factors do not change (Anders et al., 2004).

A complex interaction between static and dynamic factors contributes to the stability of the glenohumeral joint; however, the relative importance of each component in joint stability remains unclear. Shoulder dynamic stability is maintained by muscular coordination and sensory input (Veeger and van der Helm, 2007). Proprioceptive information from muscle spindles and golgi tendon organs in muscles play an important role in this stability (Dietz and Duysens, 2000).

The literature indicates that the central nervous system (CNS) can reorganize to control learned patterns of muscle activity that are essential to maintain balance during new movements in new environments (Diederichsen et al., 2002; Roy et al., 2008). New conditions cause perturbations to joint structures, because they disrupt normal movements and expose joint structures to different positions and actions that challenge the muscles and joints to respond in a coordinated fashion to control joint stress (Diederichsen et al., 2002; Roy et al., 2008).

Numerous studies have shown increases in the electromyographic (EMG) activity of the trunk and leg muscles during squatting movements (Behman and Anderson, 2005), bridge exercises (Duncan, 2009; Marshall, 2005) and traditional upper body strength exercises (Lehman et al., 2005) performed on unstable surfaces compared to stable surfaces. Nevertheless, to date little work has been done on the effects of changing the base of support (BOS) on shoulder muscle activity during closed kinematic exercises such as push-ups (Lehman et al., 2006; Ludewig et al., 2004). It is believed that proprioceptive information from numerous receptors in muscles and tendons is mediated via fast conducting nerve fibers and probably contributes more to kinesthetic sensation than information from capsule and ligaments (Diederichsen et al., 2002). The best training approach for dynamic stability is a series of exercises in functional positions with changes in balance and load on the joints (de Oliveira et al., 2008; Dietz and Duysens, 2000). Previous studies compared the size of muscle EMG at different levels of BOS, and only a few studies (Lehman et al., 2006; Ludewig et al., 2004) examined EMG onset as a dependent variable (Anders et al., 2004; Horlings et al., 2009). One study found reaction time was prologated during exercises on unstable BOS (McIlroy, 1995), but most observed no differences in reaction time for stable and unstable surfaces (Diederichsen et al., 2002; Latimer et al., 1998; McIlroy, 1995; Santos et al., 2007).

Our understanding of shoulder movement control and its dynamic stabilization is incomplete. The literature indicates that exercise with lightweight loads (1–2 kg) increases the relative EMG of the supraspinatus and infraspinatus muscles more than the EMG of the DP and UT (Brookham, 2009). Additionally, it is investigated the effects of multi-tasking on muscle EMG and reported increased middle deltoid (MD) and DP EMG during force-controlled tasks compared to postural control tasks, and decreased anterior deltoid (AD), MD, and PD EMG while performing simultaneous cognitive tasks (Antony, 2010). In the majority of published studies, only the effects of BOS (Drake et al., 2006; Lehman and Patel, 2008; Naughton et al., 2005) on muscle EMG were investigated; only a few studies have examined the effects of load and BOS on shoulder muscle EMG onset (Antony, 2010; Diederichsen et al., 2002; Santos et al., 2007).

The primary aim of the current study is to investigate the effects of BOS and external loads on EMG onset in the shoulder muscles during push-up exercises. It was hypothesized that:

1. EMG onset in the shoulder muscles decreases as external load increases.
2. EMG onset in the shoulder muscles decreases as the BOS stability reduces.

Methods

Participants

Thirty healthy individuals (17 men and 13 women, age = 23.5 range 18–36 years, weight = 63.5 ± 11/83 kg, height = 170 ± 8/3 cm), all university students, volunteered to participate in this study by a public announcement at university. Subjects were excluded if they reported any musculoskeletal conditions during the previous 12 months, any history of fracture or dislocation in the shoulder joint, surgery or severe trauma involving the upper limbs, a history of drug or alcohol addiction, or current use of painkillers. All participants were required to read an information sheet and sign a consent form prior to their participation. The study was approved by Iran University of Medical Science's Ethics Committee.

Study design

This study employed a within-subjects pretest–posttest experimental design with a washout period. Thirty healthy participants were randomly allocated to four experimental tasks (Figure 1). The research measured the effects of two loads and two stability levels on EMG onset in the shoulder muscles. EMG data were collected before and during each experimental task.

EMG recordings

EMG activity in the upper UT, LT and SA, and the long heads of the BB, PD, and TM were recorded using a multichannel portable EMG recorder (Biometrics Ltd, Gwent, South Wales, UK). Surface recording electrodes were placed over