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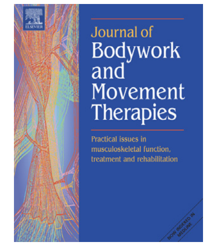

MUSCLE PHYSIOLOGY

The effect of base of support stability on shoulder muscle activity during closed kinematic chain exercises[☆]

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Summary *Method:* A total of thirty eligible subjects (17 female and 13 male, age = 22.26 ± 0.99 years, height = 170.96 ± 8.42 cm, weight = 61.63 ± 9.92 kg) were tested in six different randomly ordered positions. Surface Electromyography (EMG) was recorded from the upper trapezius (UT), lower trapezius (LT), serratus anterior (SA), long head of the biceps (LB), teres major (TM) and posterior deltoid (PD) muscles in the dominant shoulder in 6 different closed kinetic chain (CKC) positions.
Objective: To investigate changes in muscular activity of the shoulder muscles at different base of support stability levels.
Results: Muscle activity was greater in the most stable position for all muscles except UT ($P < 0.01$).
Conclusion: Shoulder muscle activity did not increase in parallel with a reduction in base of support stability in the present study.

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Introduction

The use of axial load exercises, which are known as closed kinetic chain (CKC) exercises, has grown considerably in recent years. Biomechanically, the function of each segment of the body is considered in relation to other interconnected segments. The whole body is considered as a chain with movement of one part affecting the others. The term "kinetic chain" is used to describe how the body moves, with the limbs functioning either in an open kinetic chain (OKC) or a closed kinetic chain (CKC) condition. The difference between these two conditions is determined by whether the terminal ending of the limb is free or fixed, for example, whether it is moving against a hard or soft surface. During CKC exercises a group of muscles and joints works simultaneously, whereas in OKC exercises they work separately, for example: shoulder abduction and knee extension. Examples of CKC exercises are push-ups, pull-ups, squats and lunges. All types of CKC exercises may be performed with or without weights.

There is a considerable amount of research to indicate that CKC exercises are safer and more efficient than OKC exercises for both patients and healthy subjects, especially in the early stage of rehabilitation (Fitzgerald, 1997). The majority of everyday activities and sports activities are examples of CKC exercises (Prokopy et al., 2008). During CKC exercises, compressive force, which is the result of terminal limb section stabilization, decreases the amount of shear force in active joints. During OKC exercises, the shear stress present during movement exposes the joints and muscles to risk (Graham et al., 1993).

Traumatic and non-traumatic shoulder injuries lead to functional instability in the shoulder complex. In general, coordination between mechanical (i.e. capsuloligamentous, articular, and musculotendinous structures) and dynamic restraint (i.e. shoulder muscle contraction) promotes functional shoulder stability. The sensorimotor system plays an important role in producing shoulder muscle coordination. It has been demonstrated that shoulder instability is due to a deficit in both mechanical and sensorimotor elements (Cuomo et al., 2005; Machner et al., 2003; Zuckerman et al., 2003; Barden et al., 2004). Improvement of proprioception in periarticular shoulder muscles is one of the main factors that can increase functional shoulder stability.

It has been reported that the axial load present during CKC exercises could simulate biomechanical situations that promote muscle co-activation and a significant increase of proprioceptive stimulation, compared with OKC exercises (Kibler, 1998; Wilk and Arrigo, 1993). There is solid evidence of the beneficial effects of CKC exercises (such as squat and bridging exercises) using an unstable base of support in lower-body and trunk rehabilitation, whereas the evidence for upper-limb rehabilitation is limited (Escamilla et al., 1998; Uhl et al., 2003). Facilitation of muscle activation and proprioception by means of CKC exercises has been shown in a number of studies (Ubinger et al., 1999; Timothy et al., 2001).

Generally, CKC exercises are performed with a stable or unstable base of support. Most of the literature recommends the use of a stable base of support in the early phases of shoulder rehabilitation when these exercises are safer for the individual. However, similar exercises with a relatively unstable base of support, for example a medicine ball or wobble board, are usually made use of in the advanced phases of a rehabilitation programme (Wilk and Arrigo, 1993).

It is assumed that CKC exercises using an unstable base of support make greater demands on the neuromuscular system and thus will lead to an increase in joint stability, proprioception, muscle control and muscle co-activation (Lephart and Henry, 1996; Ellenbecker and Cappel, 2000; Andrade et al., 2011). CKC exercises with an unstable base of support generate a series of patterns of movement due to the sudden changes in the direction of movement. This perturbation stimulates mechanoreceptors and results in increased joint stabilization (McMahon et al., 1996).

In recent years, research involving shoulder muscle activity during CKC exercises has been compared with respect to the use of stable and unstable surfaces using the same volunteers. The results from EMG recordings in these studies showed greater muscle activity during CKC exercises on an unstable surface. It should be noted that in the majority of these studies, shoulder muscle activity was compared during different upper limb CKC exercises, for example bench-press, wall-press and push-ups. However, there is a lack of studies using both a stable and unstable base of support during exercises that generate the same biomechanical patterns addressing load direction and intensity in upper limbs (Anderson and Behm, 2005; Marshall and Murphy, 2005).

The purpose of the present study was to determine the differences between shoulder muscle activity during CKC exercises performed with and without a stable base of support. The aim was to improve our knowledge of progressive shoulder rehabilitation in order to provide better treatment recommendations.

Methods and materials

A total of thirty eligible subjects — students at a medical university (class of 2005) — (17 females and 13 males, age $= 22.26 \pm 0.99$ years, height $= 170.96 \pm 8.42$ cm, weight $= 61.63 \pm 9.92$ kg) participated in the present study. The inclusion criteria for subjects were: no history of orthopaedic and/or neurological disorders in the neck, shoulders or upper limbs during the preceding year and no recent pain or discomfort in upper limbs. The study was approved by the state research ethics board in Iran. Subjects gave their written informed consent prior to participation.

Testing conditions

The six different test positions described in the next paragraph were randomly ordered and divided into two categories based on the amount of stability in the base support. The first category consisted of 3 different test positions with a stable base of support (the feet on the ground). The second category consisted of the same 3 different positions, but with an unstable base of support (the lower limbs were on a Swiss ball).

The six positions were numbered from most stable (Position 1) to most unstable (Position 6) (see Figure 1):

Position 1: both hands and feet on the ground
Position 2: dominant hand on a wobble board and feet on the ground