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The role of the biceps brachii in shoulder elevation

Dennis Landin [a,*], Joseph Myers [b], Melissa Thompson [a], Ray Castle [a], Jared Porter [a]

[a] Department of Kinesiology, 112 Long Fieldhouse, Louisiana State University, Baton Rouge, LA 70803, United States
[b] 4404 Forbes Tower, University of Pittsburgh, Pittsburgh, PA 15260, United States

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Abstract

The biceps brachii is a bi-articular muscle affecting motion at the shoulder and elbow. While its' action at the elbow is well documented, its role in shoulder elevation is less clear. Therefore, the purpose of this project was to investigate the influence of shoulder and elbow joint angles on the shoulder elevation function of the biceps brachii. Twelve males and 18 females were tested on a Biodex dynamometer with the biceps brachii muscle selectively stimulated at a standardized level of voltage. The results indicated that both shoulder and elbow joint angles influence the shoulder joint elevation moment produced by the biceps brachii. Further analysis revealed that the elevation moment was greatest with the shoulder joint at 0° and the elbow flexed 30° or less. The greatest reduction in the elevation moment occurred between shoulder angles of 0° and 30°. The shoulder elevation moment was near zero when shoulder elevation reached or exceeded 60° regardless of elbow angle. These results clarify the role of the biceps in shoulder elevation, as a dynamic stabilizer, and suggest that it is a decelerator of the arm during the throwing motion.

Keywords: Biceps brachii; Shoulder elevation; Joint moment

1. Introduction

The biceps brachii, like all skeletal muscle, consists of parallel bundles of multinucleate cells. The structural arrangement of skeletal muscle makes it capable of producing considerable power, with estimates around 100 W/kg (Salmons, 1995). However, while this structural arrangement is conducive to power, its disadvantage lies in a limited contraction range. This disadvantage could be problematic except that the skeletal system provides levers through which the motion of the muscle is amplified (Salmons, 1995). Consequently, the biceps brachii becomes the most powerful muscle of the anterior brachial region and acts through an extensive range of motion across the shoulder and elbow.

As one of the primary bi-articular muscles crossing the shoulder and elbow the biceps brachii plays a role in multiple motions of the upper extremity. It is a powerful supinator and elbow flexor, and has historically been included by anatomists in the shoulder flexor (elevator) group (Pickering and Howden, 1901; Salmons, 1995; Tortora, 2005; Van De Graaff, 2002; Williams et al., 1989). However, most muscle action descriptions were developed without the benefit of today's technology and it is now possible to collect precise information on a muscle's actions via instruments such as isokinetic dynamometers.

Understanding the role of the biceps brachii is also important from a clinical perspective when treating disorders of the shoulder joint. The long head of the biceps brachii can be a source of pain either as isolated biceps brachii tendonitis or other accompanying pathologies of the shoulder such as subacromial impingement, rotator cuff injuries, superior labrum anterior posterior (SLAP) lesions, and glenohumeral instability (Gill et al., 2001). In cases when conservative treatment of biceps brachii pain is unsuccessful, the long head of the biceps brachii can be excised (biceps brachii tenodesis), often resulting in good outcomes

* Corresponding author. Tel.: +1 225 578 2960; fax: +1 225 578 3680.
E-mail address: dlandin@lsu.edu (D. Landin).

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(Becker and Cofield, 1989; Gill et al., 2001; Froimson, 1975). Others have suggested that the removal of the biceps brachii might have negative affects on shoulder function (Neer, 1990), given its potential role as a humeral head depressor (Kido et al., 2000; Warner and McMahon, 1995), glenohumeral stabilizer (Itoi et al., 1993; Kumar et al., 1989; Rodosky et al., 1994), and shoulder flexor (Itoi et al., 1994). However, several studies have demonstrated that the role played by the biceps brachii at the shoulder is minimal (Furlani, 1976; Gowan et al., 1987; Levy et al., 2001; Yamaguchi et al., 1997). Thus, controversy exists as to the clinical function of the biceps brachii at the shoulder.

Clarifying the exact role of the biceps brachii at the shoulder requires investigating the joint moment it produces at the shoulder and two factors, muscle force production and the joint moment arm, are important. Variations in the force production capabilities of muscles influence the potential joint moment production. Force production is directly related to: (a) the amount of stimulation that the muscle receives, (b) its length at the moment of stimulation, and (c) its contraction velocity (Buford et al., 1997; Rassier et al., 1999). The greater the moment arm, the greater the joint moment – even if the muscle force remains constant (Bahler, 1967). However, both the joint moment arm and muscle length of the biceps brachii are altered as shoulder joint angles change (Winters and Kleweno, 1993). Furthermore, the bi-articular nature of biceps brachii means that its length must also be influenced by changes in the elbow joint angle. Therefore, the purpose of this study was to investigate the influence of shoulder and elbow joint angles on the ability of the biceps brachii to produce a shoulder joint elevation moment. It was hypothesized that the shoulder joint elevation moment produced by the biceps brachii would be reduced as shoulder and elbow flexion increase since both the joint moment arm and the muscles' length decrease.

2. Method

2.1. Participants

Participants for this study were 18 female and 12 male volunteers from the university's undergraduate population. Mean (SD) for age, height, and body mass were 20.2 (1.8) years, 1.8 (0.1) m, and 72.1 (2.0) kg, respectively. All were free of upper extremity injuries or abnormalities. Each participant read and signed informed consent documents as required by the University's Institutional Review Board.

2.2. Equipment

A Biodex System III Dynamometer (Biodex Medical Systems, Shirley, NY) measured right shoulder joint angle and the isometric torque (Nm) of the shoulder elevation moments. Contraction of the biceps brachii was electrically stimulated through surface electrodes with a Grass stimulator (model sd9b). The elbow joint was braced with removable casts in four positions (0° the anatomical position, 30°, 60°, 90°) during testing.

2.3. Procedure

The right shoulder joint of each participant was fixed at 0° (the anatomical position) and aligned with the rotational axis of the dynamometer. Electrodes were placed on the biceps brachii between the motor point and the region where the two heads merge into the common belly. The elbow angle was set at 90° and limb weight was measured prior to testing to exclude gravitational effects. The amount of electrical stimulation was standardized across the participants and determined by the following: the magnitude of 15 Hz train square wave stimulation with 10 ms pulse duration was gradually increased from 0 V. The voltage that produced an elbow flexion moment equal to 1.7% of body weight, multiplied by stature, and maintained for 5 s, was designated as the testing voltage (Li et al., 2002). This formula ensured that the voltage applied, while variable, produced the same level of stimulation in each subject. Shoulder joint elevation moments were subsequently induced by stimulation and recorded at five shoulder joint angles. Those angles were 0°, 30°, 60°, 90°, and 120°. These positions occurred in the scapular plane, which is common to most motions of the glenohumeral joint, and is located between 30° and 45° anterior to frontal plane (Andrews et al., 2004). The four shoulder angles were combined with the four elbow joint flexion angles (0, 30, 60, 90) creating 20 positions. Both the humerus and forearm were fixed in neutral positions. Consequently, the humerus was not medially nor laterally rotated, and the forearm was halfway between full supination and full pronation. In each of the 20 positions the biceps brachii was stimulated three times. The testing order was randomized for each participant (Fig. 1).

The shoulder joint elevation moment for each joint angle was recorded before, during, and after stimulation and produced the following three dependent measures: (a) passive moment (PM), which was the shoulder joint elevation moment without stimulation. This value was found by taking the mean of the shoulder elevation moment before and after the stimulation, (b) maximum moment (MM) which was the maximum shoulder joint elevation moment during the stimulation, and (c) stimulated moment (SM) which reflected the shoulder joint elevation moment produced by the stimulation and represented the difference between PM and MM.

3. Analysis

A two-factor (Shoulder × Elbow) within subject ANOVA with repeated measures was used to analyze the data, with post-hoc polynomial trend analyses and Tukey's (HSD) applied as needed. The Alpha level was set at 0.05.

4. Results

The stimulation range across all participants was 77–100 V. None of the participants experienced skin damage and very few reported lingering soreness in the hours immediately following the test. Also, there was no effect for gender across all dependent measures.

Maximum moment values are shown in Table 1. A significant elbow and shoulder interaction ($F = 4.10$, $p < .05$) was obtained. A subsequent polynomial trend analysis revealed that the influence of the elbow was linear ($F =$