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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

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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

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[*] 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 ($F =$

Table 1
Shoulder flexion maximum moment (Nm) at combinations of elbow and shoulder angles

		Shoulder angle (°)				
		0	30	60	90	120
Elbow angle (°)	0	2.05a,b	0.304	0.04	0.01	0
	30	2.31a,b	0.38	0	0.02	0
	60	1.57a,b	0.36	0	0.022	0
	90	0.82	0.64	0.16	0	0.02
	Mean	1.68	0.42	0.05	0.01	0.005

Note: a is significantly different from all but b.

Table 2
Shoulder flexion passive moment (Nm) at combinations of elbow and shoulder angles

		Shoulder angle (°)				
		0	30	60	90	120
Elbow angle (°)	0	0.94b	0.004	0	0	0
	30	1.21a	0.13	0	0	0
	60	0.79	0.1	0	0.002	0
	90	0.41	0.22	0.14	0	0
	Mean	0.83	0.11	0.03	0.005	0

Note: a is significantly different from all but b.

Table 3
Shoulder flexion stimulated moment (Nm) at combinations of elbow and shoulder angles

		Shoulder angle (°)				
		0	30	60	90	120
Elbow angle (°)	0	1.11a	0.3	0.04	0.01	0
	30	1.1b	0.25	0	0.02	0
	60	0.78b	0.26	0	0.02	0
	90	0.41	0.42	0.02	0	0.02
	Mean	0.85	0.03	0.01	0.01	0.005

Note: a is significantly different from all but b.

8.07, $p < .05$) while the shoulder's influence was both linear ($F = 15.07$, $p < .05$) and quadratic ($F = 11.50$, $p < .05$). As the shoulder angle moved from 0° to 30° the MM reduced dramatically regardless of the elbow angle with a mean torque of .421 Nm. As the shoulder was moved to 60° of elevation the MM was negligible for all elbow angles and remained so across the 90 and 120 shoulder positions.

Data were also collected on the joint moment when the stimulation was absent (Table 2). A significant interaction between the elbow and shoulder positions was also noted here where the influence of the shoulder was linear ($F = 15.02$, $p < .05$) and quadratic ($F = 15.68$, $p < .05$). As with the MM results the PM decreased substantially when the shoulder angle changed from 0° to 30°. The mean torque at 30° of shoulder elevation, regardless of elbow angle, was .115 Nm. From 60° to 120° of shoulder elevation the PM was nearly non-existent regardless of the elbow angle.

Fig. 1. Example of experimental set-up. Subject is depicted with her arm in one of the 20 testing positions.

Results for the SM followed the same general pattern as MM and PM. A significant elbow and shoulder interaction was obtained with the elbow's influence being linear ($F = 5.46$, $p < .05$) and the shoulder's being both linear ($F = 8.83$, $p < .05$) and quadratic ($F = 6.56$, $p < .05$). The greatest change in SM occurred as the shoulder was flexed from 0° to 30° (Table 3). The mean torque at 30° on the shoulder was .307 Nm and continued to decline across the remaining combinations of shoulder and elbow angles.

5. Discussion

The biceps brachii has long been described in the anatomy literature as having a role in shoulder elevation. We examined how selected combinations of shoulder and elbow angles influence this function. The most dramatic finding was that the shoulder elevation moment decreased significantly (about 65%) as the shoulder angle progressed from 0° to 30°. This pattern held across all elbow angles except for the 90° position, which showed a much smaller percent decrease (22%) in the elevation moment through the 30° shoulder position. The stimulation had little effect when the shoulder angle reached 60° and remained negligible through the 90° and 120° positions regardless of elbow angle.

These findings may be explained in part by the changes in the biceps brachii's length as the elbow and shoulder angles vary. The longer a muscle, the greater will be the length of its passive components and this will yield higher passive forces. As shoulder elevation and angle flexion increased the length of the biceps decreased resulting in reductions in the passive moment. While the active elements can also elongate there is an optimal length over which a muscle can actively generate force (i.e. its excursion capacity) and it varies across muscles (Buford et al., 1997; De Wilde et al., 2002; Murray et al., 2000; Winters and Kleweno, 1993). It appears that the optimal length for the biceps brachii in shoulder elevation, while moving through the scapular plane, is achieved with the shoulder at 0° and the elbow at 30° or less. Therefore, from an anatomical perspective the action of the biceps brachii at the shoulder is quite limited and it influences motion at that joint only when it is near maximal length.

For years, clinical researchers have sought to understand the role of the played by the biceps brachii at the shoulder, with conflicting results. At the shoulder the biceps brachii is thought to act as a shoulder elevator. Several studies, utilizing electromyography and have provided useful information related to the bicepital activation patterns during shoulder movements. Generally the results have demonstrated that the biceps brachii plays a very small role in shoulder movements (Furlani, 1976; Gowan et al., 1987; Levy et al., 2001; Yamaguchi et al., 1997). The results of the current study, which added isokinteic dynamometer technology to electromyography, support those findings by demonstrating that the biceps brachii has only minimal influence on shoulder elevation. Our findings indicate that although the biceps is contracting throughout scapular elevation it is not necessarily contributing much to the movement.

The biceps brachii is considered by some clinicians to function as a dynamic stabilizer of the shoulder joint and this role is thought to be most evident as the shoulder approaches mid elevation (Paxinos et al., 2001). The work by Kido and his colleagues (Kido et al., 1998, 2000) supports this by demonstrating that the biceps brachii may have a significant role in dynamic stabilization by depressing the humeral head when rotator cuff lesions are present. Superior humeral head translation has also been demonstrated when the long head of the biceps brachii is compromised (Warner and McMahon, 1995). Our results support this position to some degree, but only when the shoulder is progressing through the early stages of elevation. In low elevation positions, based upon the shoulder flexion moment it produces, we would argue that the biceps brachii has a prominent role in stabilizing the shoulder. However, once elevation reaches 30° or more, the biceps brachii produces a negligible shoulder moment and cannot, therefore, exert much force on the joint. Consequently, its potential as a dynamic stabilizer is minimal.

While our results suggest limitations to the dynamic stabilizing action of the biceps brachii, its role as a possible passive stabilizer cannot be ignored. The long head of the biceps brachii is known to contribute to anterior stability of the glenohumeral joint by increasing the shoulder's resistance to torsional forces in the vulnerable abducted and externally rotated position (Rodosky et al., 1994). The biceps brachii also helps to diminish the stress placed on the inferior glenohumeral ligament.

Our findings may be used to guide the planning of rehabilitation exercises following shoulder instability injuries, particularly atraumatic multidirectional and acquired instabilities. The atraumatic form of instability generally occurs secondary to congenital laxity in the shoulder and it can be managed fairly well with long-term therapy focused on strengthening the shoulder's dynamic stabilizers (Mazoue and Andrews, 2004; Malanga et al., 1999). Acquired instabilities occur over time and are created by repetitive stresses (as during the overhead throwing motion) that lead to stretching and eventual damage of the passive and active stabilizing tissues. This instability is also initially treated with therapy targeting the dynamic stabilizers of the shoulder (Mazoue and Andrews, 2004).

Since the biceps brachii can be injured in overhead motions, particularly in the release and deceleration phase of the throwing motion, it is typically included in shoulder rehabilitation and strengthening programs. Common injuries involving the biceps brachii in this phase of throwing include labral tears near the attachment of the long head and subluxation of the tendon of the long head (Andrews et al., 2004). Our results support the biceps brachii involvement in deceleration and suggest that it may be most heavily involved in the later stage of this phase, that is, as the arm moves through the final 30°. Consequently, it may be most appropriate for rehabilitation exercises involving the biceps brachii to focus on the initial phase of shoulder elevation, which will increase the ability of the biceps brachii to stabilize the joint. Furthermore, since the biceps brachii is frequently injured when decelerating the arm, an emphasis should be placed on eccentric actions at the end of the overhead throwing motion, which more closely approximate conditions under which the biceps brachii is injured.

6. Limitations

Limitations on this project accrue mostly to four factors. First, the Grass Electrical Stimulation generator produced a maximum of 100 V. It is possible that more powerful, yet still standardized, stimulations may have produced greater joint moments. Second, and related, discomfort produced by the stimulation most likely would preclude the use of a more powerful electrical stimulation. A third limitation is that our findings are limited to healthy subjects with no history of shoulder injury or instability. How our findings apply to unstable or repaired shoulders is unknown. The fourth and final limitation is that the forearm was positioned neutrally, halfway between pronation and supination. Since the biceps brachii is a powerful supinator, it is possible that a fully supinated forearm may create changes in how the biceps works at the shoulder. This merits further investigation.

7. Conclusion

The results of this study indicate that the biceps brachii has a role in shoulder elevation but only in the early phase of the movement, in contrast to the conventional view that this muscle acts throughout the elevation motion. The present data indicate that the biceps brachii's role is limited to the early phase of elevation and becomes negligible as shoulder elevation and elbow flexion increase.

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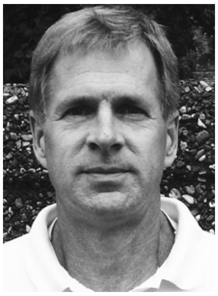

Dennis Landin is an associate professor in the Department of Kinesiology at Louisiana State University. He is the coordinator of the human anatomy curriculum and conducts research in musculoskeletal functioning.

Joseph B. Myers, PhD, ATC is an Assistant Professor in Sports Medicine (School of Health and Rehabilitation Sciences) and Assistant Professor Orthopaedic Surgery (School of Medicine) at the University of Pittsburgh. His responsibilities include Coordination of Graduate Education of Sports Medicine and Associate Director of both the Neuromuscular Research Laboratory housed within the Department of Orthopaedic Surgery and the University of Pittsburgh Medical Center Golf Fitness Laboratory.

Melissa Thompson, a Certified Athletic Trainer, received an undergraduate degree in Exercise Science from Truman State University in 2000 and a graduate degree from the University of Virginia in 2001. She has worked at the United States Military Academy and is currently on the faculty at Louisiana State University as an Instructor in the Department of Kinesiology.

Ray Castle, PhD, ATC, received his B.S. degree in Kinesiology from Louisiana State University (1990), and M.S. (Human Performance–Exercise Science) and PhD (Human Performance–Administration and Teaching) degrees from the University of Southern Mississippi (1993; 2000). He currently serves as Assistant Professor of Professional Practice and Director of the CAATE-accredited undergraduate Athletic Training Concentration in the Department of Kinesiology at Louisiana State University (Baton Rouge, LA) and is on the Education Council Executive Committee of the National Athletic Trainers' Association (NATA).

Jared M. Porter is a motor behavior doctoral student in the Department of Kinesiology at Louisiana State University. Jared's research interests include motor learning, skill acquisition and practice schedule design.