

ARCHITECTURE OF THE BICEPS BRACHII CHARACTERIZED WITH ULTRASOUND AND MRI

D. J. Asakawa^{1,2}, G. Pappas^{1,2}, S. L. Delp¹, and J. E. Drace²

¹Biomechanical Engineering Division, Mechanical Engineering Dept., Stanford University

²Diagnostic Radiology Center, Palo Alto VA Health Care System, Palo Alto, California

Email: djasakawa@stanford.edu

INTRODUCTION

Cine phase contrast magnetic resonance imaging (cine-PC MRI) allows examination of muscle-tendon motion *in vivo* (Drace & Pelc, 1994). Relating changes in velocity and strain calculated from cine-PC MRI to the underlying muscle contraction mechanics requires detailed knowledge of a muscle's architecture and its effect on the trajectory of muscle tissue during contraction. Specifically, knowledge of the extent of tendon within the muscle must be known to interpret its effect on muscle motion. Also, orientation of the muscle fascicles with respect to the tendon, and the change in fascicle orientation with flexion, must be understood to calculate strain along a fascicle. These architectural characteristics have not been previously reported for the biceps brachii muscle. The purpose of this study, therefore, was to characterize (i) the extent of the biceps aponeurosis within the muscle, (ii) the orientation of the distal fascicles with respect to the tendon, (iii) the change in orientation of the fascicles with flexion of the elbow. Ultrasound imaging has been used effectively to study muscle architecture (Rutherford & Jones, 1992; Fukunaga et al., 1997). We used MRI and ultrasound imaging to characterize biceps brachii architecture and provide the basis for interpretation of *in vivo* measurements of muscle-tendon motion.

METHODS

Static axial MR images of the biceps brachii were acquired from 12 subjects (10 male, 2 female, age: 21 to 44 years, height: 5'3" to 6'2") with a 1.5T GE scanner. The extent of the aponeurosis within the muscle and the length of the biceps brachii long head

muscle were measured from these images using GE image analysis software.

We acquired ultrasound images of the biceps brachii from the same subjects with the elbow extended and with the elbow flexed 90° while the subject resisted a load equal to 5% of their maximum voluntary contraction (MVC) strength. An Acuson Sequoia 512 Ultrasound System (Mountain View, CA) with a 52-mm, 15-MHz transducer was used to obtain the images. The transducer was oriented to produce a sagittal plane image of the biceps brachii with the distal aponeurosis evident (Fig. 1).

NIH Image software was used to quantify the angles between clearly evident fascicles and the aponeurosis. We recorded angles in the distal muscle in two separate regions: 0-2 cm, and 2-4 cm proximal to the point where the most distal fiber inserted into the tendon. We measured angles of fascicles anterior and posterior to the aponeurosis. Paired t-tests were performed to compare fascicle insertion angles with the elbow extended to fascicle insertion angles with the elbow flexed.

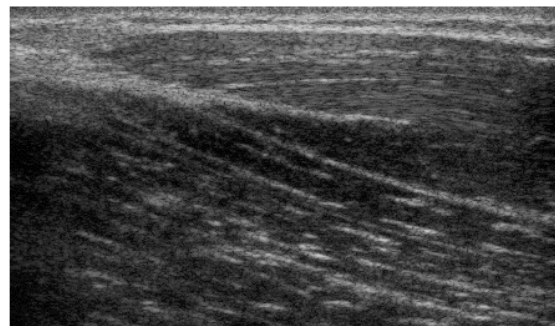


Figure 1: Ultrasound image of the distal biceps brachii ; the distal tendon (upper left) continues as an internal aponeurosis. Fascicles are visible inserting into the aponeurosis.

Table 1: Average Fascicle Insertion Angles for the Distal Biceps Brachii

Elbow Extended				Elbow Flexed 90° with 5% MVC			
Anterior		Posterior		Anterior		Posterior	
0-2cm	2-4cm	0-2cm	2-4cm	0-2cm	2-4cm	0-2cm	2-4cm
17°	14°	14°	12°	21°	18°	17°	15°

RESULTS

The central aponeurosis extended 34% of the length of the biceps brachii muscle on average. The average aponeurosis length was 7 ± 1 cm in the 12 subjects. The length of the entire biceps brachii long head muscle averaged 20 ± 2 cm with the arm flexed approximately 10° , consistent with An et al. (1981) and Murray (1997).

There was asymmetry between the anterior and posterior fascicle insertion angles. The average insertion angle for fascicles anterior to the aponeurosis was 17° for the distal 2 cm of the muscle with the elbow extended (Table 1). The posterior fascicles in this same region inserted at 14° with the elbow extended. Fascicles anterior to the aponeurosis inserted at a significantly greater ($P \leq 0.05$) angle than the fascicles posterior to the aponeurosis in both regions (0-2cm and 2-4cm) when the elbow was extended. With the elbow flexed, resisting 5% MVC, only fascicles within the distal 0-2 cm of the muscle showed a significant difference in anterior and posterior insertion angles.

Fascicle insertion angles with the elbow flexed and resisting 5% MVC were significantly higher ($P \leq 0.05$) than angles measured with the elbow extended for all regions of the muscle studied. For example, fascicle insertion angles anterior to the aponeurosis increased with elbow flexion from 17° to 21° in the distal 0-2 cm of the muscle and from 14° to 18° in the distal 2-4 cm of the muscle.

DISCUSSION

The biceps brachii is generally considered to be a parallel-fibered muscle, but distal fascicle insertion angles can influence muscle contraction mechanics such as change in fascicle length with flexion. We found that fascicle insertion angles at the distal end of the biceps brachii muscle were asymmetric with respect to the aponeurosis. Fascicle insertion angles increased $3-4^\circ$ with a 90° change in joint angle accompanied by application of a 5% MVC load. This increase in fascicle insertion angle was small but consistent across subjects. In addition, the extensive aponeurosis has the potential to influence the motion of distal muscle tissue as well as muscle tissue along the longitudinal axis of the muscle.

We used this characterization of biceps brachii architecture to aid in the interpretation of muscle tissue velocity and strain calculated in the same subjects using cine-PC MRI. Detailed knowledge of muscle architecture is also useful when interpreting the effects of assumptions made in modeling muscle contraction mechanics for the biceps brachii.

REFERENCES

- Drace, J.E., Pelc, N.J. (1994) *J. MRI*, **4**,157-163
 Rutherford, O.M., Jones, D.A. (1992) *Eur. J. Applied Physiology*, **65**, 433-437
 Fukunaga, T. et al. (1997) *J. Biomech*, **30**,457-63
 An, K.N. et al. (1981) *J. Biomech* **14**, 659-669
 Murray, W.M (1997) PhD Thesis, Northwestern University, Evanston, IL

ACKNOWLEDGMENTS

Funding provided by NIH Grants HD31493 & HD33929, the Department of Veterans Affairs, and a Whitaker Foundation Graduate Fellowship.