Brachioradialis Muscle Function During Forearm Rotation from EMG, Anatomy, and Biomechanical Modeling

+1Bader, JS; 1Boland, MR; 1Spigelman, T; 1Uhl, T; 1Pienkowski, D
+1University of Kentucky, Lexington, KY
Senior author: joseph.bader@uky.edu

INTRODUCTION:
Quantification of muscle function is essential for the solution of musculoskeletal challenges. Accurate muscle placement data is needed to understand the role of individual muscles and their contribution to overall biomechanical function. The most commonly used methods of determining muscle function involve electromyography (EMG), however this only elucidates muscle activity and is thus insufficient. To improve our understanding of forearm motion as well as forces across the distal radio ulnar joint, this study incorporated EMG data with muscle length analysis and biomechanical modeling to clarify the function of the Brachioradialis (BRAR) muscle during forearm pronosupination.

METHODS:
This study had two components: one cadaveric, the other in vivo. Regarding the first component, the origin and insertion of 15 muscles were marked on the upper extremity of nine fresh cadaver specimens. The positions of these muscles were digitally measured at various stages of pronation (P) and supination (S) by using an electromagnetic 3D tracking sensor (Motion Star, Ascension Technologies, Burlington, VT). Data were collected for the muscles at 10° increments of simulated forearm pronosupination (PS) throughout the entire range of motion. Coordinates of the origins and insertions were recorded to determine the length of the muscles of interest. For the purposes of this study, the assumption was made that the muscles formed a straight line from the origins to the insertions. The lengths of the muscles were normalized as a percentage of the longest length observed during rotation. The muscle data was also used to create a vector based model of the forces occurring at the distal radioulnar joint (DRUJ) (1). This model was based on maximum muscle forces from physiological cross sectional area data. Joint reaction forces were calculated about the transverse axis (radio-ulnar axis) and the shear axis (palmar-dorsal axis). The resultant force acting at the DRUJ was determined from the result of the shear and transverse forces. To determine the role that brachioradialis (BRAR) had on DRUJ loading, the muscle was removed from the model. The forces at each position were averaged for each of the nine specimens before and after BRAR removal.

For the in vivo component of this IRB approved study, subject consent was first obtained. Then, a fine-wire electrode was placed in the BRAR of twelve subjects, approximately 5cm below the lateral epicondyle. In addition, an electromagnetic tracking sensor was attached to each subject’s arm so that the angle of forearm rotation could be measured in conjunction with the EMG signal. The subjects were asked to grab a handle with an 18N load attached to it. They were then asked to dynamically move their hand from pronation to neutral and back, and then from supination to neutral and back. Each task was performed five times. To make the EMG data comparable to the cadaveric data, the EMG data was divided into 10° arcs based on the angle provided by the electromagnetic tracking system. The data were also grouped by whether the forearm was rotating in the direction of pronation or the direction of supination. All EMG values were then normalized as a percentage of the maximum signal observed for each individual subject. The values contained within each arc for a specific subject were then averaged. The final value for each 10° increment was obtained from the average of all subjects. The normalized muscle length and EMG data were then compared.

RESULTS:
Muscle length data (Fig.1) shows that the BRAR is shortest at neutral and longest as the forearm reaches its maximum position in either direction. EMG data shows that as the arm pronates from full supination, EMG activity decreases from its maximum to its minimum around neutral and then slightly increases toward full pronation. As the arm supinates from full pronation, the EMG signal increases. The BRAR effect on calculated DRUJ loading is shown (Fig. 2).

DISCUSSION:
The results of this study show that the BRAR muscle has important roles in forearm motion and it also has a key role in governing the amplitude of forces across the DRUJ. As clearly shown by the EMG data, the BRAR muscle initiates pronation through a concentric contraction. Second, the BRAR muscle decreases transverse forces for most of the range of PS, while acting to compress the joint at full pronation or supination. Third, along the dorsal palmar axis, the BRAR works to reduce the amplitude of DRUJ loads except near mid-rotation. The supination curve increases from neutral to full supination where the muscle is at its longest. This would be consistent with an eccentric contraction which would help slow the resulting supinating motion.

When the forearm is in a neutral position and supporting an object of significant weight, the BRAR protects the DRUJ by lifting the radius up off the ulna, thereby protecting the ulna from a significant bending moment. In terminal PS, firing of the BRAR dynamically assists in generating stability from translational motion at the DRUJ.

This research shows that the BRAR appears to function more with pronator muscle actions than with supinator muscle actions. These findings are novel and will help shed light on the potential biomechanical consequences of muscle loss in injury or tendon transfer procedures.

REFERENCES: (1) Bader, JS et al., Combined ORS (2007), Paper #268.