The Function of Brachioradialis
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Purpose  The function of the brachioradialis muscle is controversial. The objective of this study was to determine primary and secondary functions of the brachioradialis under various loading tasks as measured by EMG.

Methods  Ten healthy individuals (9 men, 1 woman; average age, 34 years ± 10; average height, 175 cm ± 7; average weight, 76 kg ± 13) performed elbow flexion with the forearm in 1 of 3 positions (neutral, pronation, and supination) with 4 different loads (0, 22, 45, and 67 N). The elbow was flexed to 90° as the volunteers performed 2 separate movements: (1) from full supination to neutral and (2) from full pronation to neutral using 4 different loads (0, 9, 18, and 27 N). Each movement started and ended in supination and pronation, respectively. Fine-wire EMG electrodes were placed in the brachioradialis, and kinematic data were collected using an electromagnetic motion analysis system. The EMG data were reported as a percentage of maximal voluntary isometric contraction and were ensemble averaged from 5 trials of each exercise condition for statistical analysis.

Results  No difference in muscular activation was found during elbow flexion tasks in the 3 forearm positions. Significantly greater activation was found during concentric (23% maximal voluntary isometric contractions ± 5% maximal voluntary isometric contractions) than during eccentric (11% maximal voluntary isometric contractions ± 5% maximal voluntary isometric contractions) phases during elbow flexion. Brachioradialis mean activity during concentric pronation and eccentric supination with the heaviest loads 18 and 27 N was significantly greater than activity during concentric supination and eccentric pronation.

Conclusions  The greatest EMG activity recorded from the brachioradialis occurs during elbow flexion tasks regardless of forearm position indicating that the primary function of the brachioradialis is as a consistent elbow stabilizer during flexion tasks. During rotational tasks, more EMG activity was recorded during pronation compared with that during supination tasks indicating a secondary function of the brachioradialis as a pronator. (J Hand Surg 2008;33A:1853–1859. Copyright © 2008 by the American Society for Surgery of the Hand. All rights reserved.)

Key words  Distal radioulnar joint, electromyography, muscle function, pronation, supination.

The brachioradialis muscle originates from the lateral supracondylar ridge, the lateral aspect of the diaphysis of the humerus, and the lateral intermuscular septum and inserts into the lateral aspect of the styloid process of the radius. Controversy with regard to its function can be found as far back as 1756 when Chelseden wrote “Supinator Radii Longus . . . is not a supenator but a bender of the cubit, and that with a longer lever . . . is less concerned about turning the cubit supine than either the extensors of the carpus, fingers or thumb.” In 1925, Jackson wrote “The Brachioradialis (Supinator Radii Longus) . . . flexes the forearm. This action is strongest when the forearm is pronated. It acts as a supinator only when the arm is extended and pronated. It then serves to put the arm in a state of semi-pronation. When the forearms flexed and supinated, it acts as a pronator.” This seems to be in general disagreement with most modern opinions,
which state that it is an elbow flexor alone, and with older opinions, which gave it the name *supinator longus*. McMinn does concede that the brachioradialis has some weak pronating action from the fully supinated position. In more recent times, other methods have been used to attempt to work out the function of the brachioradialis. Murray et al. used moment vector analysis to study moment arms of muscles across the elbow in varying forearm positions. This model calculated that the brachioradialis has a pronation moment arm when the forearm is supinated and a supination moment arm when the forearm is pronated. Naito et al. used dynamic EMG to study forearm rotation in static elbow positions, and their conclusion was that brachioradialis has minimal EMG activity when no load was placed on it and had less activity during a supination motion than during a pronation motion. The objective of this study was to determine the function of the brachioradialis during elbow flexion and forearm rotation under various loading tasks as measured by EMG.

**MATERIALS AND METHODS**

**Participants**
Ten healthy men and women volunteered to participate in this study. The group consisted of 1 woman and 9 men with an average age of 34 years (SD, 10), average height of 175 cm (SD, 7), and average weight of 76 kg (SD, 13). All participants were examined by a physician to ensure no previous medical conditions or forearm and/or wrist pathology existed. Participants were excluded if they had a prior surgery, injury, arthritis involving the elbow, neurologic disorders, aversion to needles, or allergies to adhesive tape. Participants were also asked to demonstrate adequate strength by completing an elbow flexion task using 67 N and a forearm rotation task using 27 N prior to initiating the study. Institutional review board approval was obtained for this study.

**Study design**
This was a single-occasion, nonclinical, basic science study to evaluate the function of the brachioradialis. Independent variables were elbow flexion tasks in 3 forearm positions (pronated, supinated, and neutral) and forearm rotation tasks (supination to neutral and pronation to neutral) under 4 different loaded conditions. Dependent variables were EMG activity represented as a percentage of maximal activation and time of maximal activation during a task. Testing was carried out in the musculoskeletal laboratory.

**Procedures**
An electromagnetic motion analysis sensor “Flock of Birds” (Ascension Technologies, Burlington, VT) was used to synchronously record kinematic data of the forearm and humerual segments with EMG data. One electromagnetic sensor was attached to the lateral humerus, and another sensor was attached just proximal to the wrist on the dorsal surface of the forearm. Sensors were attached using double-sided adhesive tape and nonwoven bandage (Cover Roll, Beiersdorf AG, Hamburg, Germany). Nonadherent bandage (Coban; 3M, St. Paul, MN) was used to secure the sensors at the forearm to minimize skin motion. Subjects stood with arms in a neutral position for a static recording to define joint centers of rotation and create reference anatomic segments for kinematic data collection. These data were used to track the forearm motions.

The skin overlying the brachioradialis was cleaned with alcohol. Two sterile, bipolar, 50-µm fine-wire electrodes were inserted 1 cm apart using a 2-needle insertion technique to prevent recording electrodes from grounding out their signal. Electrodes were placed approximately 3 cm below the lateral epicondyle, and the 25-gauge needles were immediately removed leaving the indwelling fine-wire electrodes in the brachioradialis. The fine-wire electrodes were taped to the skin to minimize movement artifact, and the other end of the electrodes were attached to metal spring adapters. The subject was asked to flex his or her elbow 3 to 4 times to set the electrodes in the muscle and to allow visual confirmation of primary muscular activity of the brachioradialis from the needle insertion. The ground electrode was placed on the contralateral acromion.

EMG data were collected at 2000 Hz using a portable amplifier (Myopac, Mission Viejo, CA). The kinematic data were collected at 100 Hz using the Motion Monitor software system (Innovative Sports, Chicago, IL). The kinematic and EMG data were collected synchronously through the Motion Monitor system. Prior to elbow flexion and rotation tasks, resting and maximal EMG activity was recorded from the brachioradialis. Two resting files were recorded to represent baseline resting activity prior to initiating a specific movement task. This resting baseline EMG activity allows for removal of background activity and noise from EMG data collection. The first resting trial was performed with the arm hanging at the subject’s side and was used to represent baseline resting activity for flexion tasks. The second resting file was collected with the unsupported elbow flexed to 90° and wrist in a natural relaxed posture to represent baseline resting activity for rotational tasks. We assumed a low level of EMG activity...
would be present from just holding the weight of the forearm at 90° without the additional stress of the rotation tasks. These resting activities were subtracted from signals collected during the experimental task and maximal voluntary contraction to better represent muscular activity associated with tasks. Two maximal voluntary isometric contractions (MVICs) of the brachioradialis were performed for 5 seconds with the elbow flexed to 90° and the wrist in neutral to determine the maximal activation of the brachioradialis. Subjects were allowed to practice this prior to performing the 2 trials. A 1-minute rest was given between trials to prevent fatigue. A single MVIC was performed at the end of data collection to ensure wire electrodes did not migrate during the study. A repeated-measure analysis of variance comparing measures before and after MVIC migrate during the study. A repeated-measure analysis of variance comparing measures before and after MVIC revealed no significant difference (p > .05). An intra-class correlation coefficient (ICC2,1) revealed a value of .79 supporting consistency of electrode placement throughout the test.

We instructed subjects to perform a series of elbow flexion and forearm rotation exercises to compare muscular demand during these activities. The order of exercise tasks was randomized to prevent fatigue and bias during the testing session. Through pilot testing, the exact same load could not be used during the 2 tasks because the torque demands during the rotational task were too demanding because the loads that could be reasonably managed for elbow flexion tasks were heavier than forearm rotational tasks. Subjects were given 1 minute rest between each exercise condition to minimize fatigue effects. Elbow flexion tasks were performed in 3 positions (supinated, neutral, and pronated) using 4 different loads (0, 22, 45, and 67 N) with 5 repetitions of each condition. We instructed subjects to perform the elbow flexion task from 0 to 130° while keeping pace with a metronome to attempt to direct subjects to move through a consistent velocity of 130°/s during all flexion tasks.

Two forearm tasks (pronation to neutral, supination to neutral) were performed with the elbow unsupported and flexed to 90°. Each task was further subdivided into 2 phases for data analysis. Pronation to neutral task started with the forearm in full pronation and moved to a neutral position; this phase was called concentric supination. Forearm rotation back to the starting position was termed eccentric pronation. Supination to neutral started in a full supinated position and moved toward neutral (called concentric pronation) and returned to the start position (this phase was termed eccentric supination). Four loads (0, 9, 18, and 27 N) were attached to a polyvinyl chloride jig created specifically for this study so that the loads would not shift during rotational tasks. The center of the load was placed 20 cm away from the radial side of the hand. During the forearm rotation tasks, the torque created by the applied loads was 0, 1.8, 3.6, and 5.4 N·m, respectively. We instructed subjects to perform each motion in synchrony with a metronome to control velocity of motion. Loads for both the elbow flexion and rotational tasks were determined via pilot data and represented activities of daily living with the goal of placing a moderate load on the arm. Elbow flexion loads were progressively increased by 22 N. These loads are similar to those of daily activities such as lifting a gallon of milk or a bag of groceries. Rotational torques at the same loads were initially attempted during pilot testing. The extreme difficulties in performing the task required use of much lighter loads so not to injure subjects. Our goal was to represent a moderate level of difficulty during rotational tasks without extremely fatiguing the participant as several trials would be performed during this study. This requirement necessitated use of much lighter loads during the rotational tasks. The loads represent moderate to heavy torques as recently reported peak torque values range from 6.0 to 12.0 N·m produced by females and males respectively during a rotational task.

### Data reduction

The kinematic data was filtered with a low-pass cutoff threshold of 6 Hz with a 4th order Butterworth filter. The kinematic data allowed for the mean EMG data to be divided and analyzed in 2 phases, the concentric lifting phase (starting in elbow extension to maximal elbow flexion) and eccentric lowering phase (beginning in maximal elbow flexion and returning to elbow extension, start position) during the elbow flexion tasks. Concentric elbow flexion was defined as the motion of the hand moving superiorly toward the shoulder. Eccentric elbow flexion was defined as the muscle activity as the arm returned to the fully extended starting position. The 2 rotational tasks were further divided into concentric and eccentric phases for EMG analysis as previously described. All raw EMG signals were digitally band pass–filtered between 10 and 1000 Hz and smoothed with a root mean square algorithm with a time constant of 20 milliseconds. The root mean square amplitude of the highest 500 milliseconds during the initial MVIC was used to represent 100% MVIC. The resting data from the second position with elbow flexed...
was removed prior to determining MVIC. All EMG data collected during the tasks were analyzed using the same root mean square algorithm, and the mean EMG amplitude during the exercise task is represented as a percentage of the MVIC activity with the appropriate resting EMG activity being removed to delete background activity for the particular task. The 5 exercise trials were ensemble averaged to normalize all data to 100% cycle for a particular task. This procedure is commonly done to account for small time difference during a movement task. This procedure allows the concentric and eccentric phases of each activity to be divided into equal 50% portions. All data were processed with Datapac 2k2 software (Run Technologies, Mission Viejo, CA).

Statistical analysis
The purpose of this study was to determine the function of the brachioradialis using indwelling EMG during flexion and rotation tasks. Nonparametric Friedman’s repeated-measures analyses were used on these data due to small number of subjects, and the data were not normally distributed. Significance was set a priori at an alpha level < .05. Any significant differences were further analyzed with a post hoc analysis using a Wilcoxon signed rank test to compare differences between paired conditions. Our initial aim was to determine if there was a difference between pronation, supination, and neutral forearm positions during elbow flexion tasks. The second aim was to evaluate if there was a difference in EMG amplitudes between the concentric and eccentric phases during the elbow flexion tasks. The third aim was to determine which phase of rotational tasks activates the brachioradialis to the greatest degree. The fourth aim was to compare similar loads during the flexion task and during forearm rotational task to determine which task activated the brachioradialis to the greatest degree and therefore to determine the primary role of the brachioradialis as either an elbow flexor muscle or a forearm rotator. The closest loads used during elbow flexion and forearm rotation tasks were 22 N and 27 N, respectively, therefore these were used in the statistical comparison. A Wilcoxon signed ranked test was performed to compare EMG activity between the 2 tasks. All statistical analyses were assessed with Statistical Package for Social Sciences (SPSS v12.0; SPSS Inc., Chicago, IL).

RESULTS
During elbow flexion, no significant differences were found between the positions of the forearm in elbow flexion tasks (p > .05; Table 1). Based on this result, concentric and eccentric EMG activity differences were compared using pooled data from the 3 different forearm positions. Concentric activity was consistently greater than eccentric activity for all 4 loads (p < .01; Fig. 1). Differences in EMG activity were found between forearm rotation phases (p < .01). Concentric pronation and eccentric supination to neutral phases of the supination to neutral task at 18 and 27 N were the only phases to be found to have significantly greater EMG activity than did eccentric pronation and concentric supination phases of the pronation to neutral task (p < .01; Table 2). To investigate whether the brachioradialis performed primarily as an elbow flexor or as a forearm rotator, we compared the 22 N elbow flexion task to the 27 N rotation task with phases of the task pooled together. A Wilcoxon signed rank test revealed that

| TABLE 1. Comparison of Forearm Position During Elbow Flexion Task |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                      | 0 N       | 22 N      | 45 N      | 67 N      |
|                      | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| Concentric           |       |     |       |     |       |     |       |     |
| Neutral              | 7    | 4   | 19   | 7   | 27   | 9   | 44   | 10  |
| Pronated             | 8    | 6   | 18   | 5   | 28   | 9   | 40   | 8   |
| Supinated            | 6    | 4   | 20   | 8   | 27   | 8   | 42   | 8   |
| Eccentric            |       |     |       |     |       |     |       |     |
| Neutral              | 5    | 4   | 10   | 5   | 11   | 6   | 19   | 7   |
| Pronated             | 6    | 6   | 10   | 4   | 13   | 6   | 19   | 5   |
| Supinated            | 5    | 4   | 10   | 5   | 11   | 7   | 20   | 5   |

Note: The table provides descriptive EMG data from all forearm positions during elbow flexion tasks. There is no difference between positions; however, there is increasing EMG activity as the loads were increased. All data are reported as percentage of MVIC activity (%).
the brachioradialis activity during elbow flexion tasks was greater (p < .01; Fig. 2).

**DISCUSSION**

Our results agree with past research that the primary function of the brachioradialis is as a concentric elbow flexor and secondarily assists in forearm pronation.\(^1\) This agrees with the description of the muscle function by Chelseden in 1756 who noted the brachioradialis function was more of a flexor and less of a supinator, implying the brachioradialis functioned more in pronation.\(^1\) In the supination to neutral task, the brachioradialis acted concentrically to move the forearm from a fully supinated position into a neutral position. Returning from neutral to fully supinated position, the brachioradialis acts eccentrically to decelerate the forearm.

These findings are consistent with those of Jamison and Caldwell\(^12\) who studied the brachioradialis using torque analysis and surface EMG in an isometric position of pronation/supination, using maximal voluntary contraction. They found that the brachioradialis EMG tended to be enhanced by flexion and pronation tasks and reduced during flexion and supination tasks.\(^12\) Further evidence of the pronation role of the brachioradialis can be found in the studies by Naito et al.\(^13,14\) where they used dynamic EMG with fine-needle electrodes but in a static position of elbow flexion. These methods and findings agree with the current study where the forearm was held at 90° of flexion while rotation motions took place. Both Jamison and Caldwell and Naito et al. have shown a reciprocal role between biceps brachii and the brachioradialis with the biceps showing increasing activity in supination and the brachioradialis in pronation.\(^7,12\)

There may also be an inhibitory projection from the brachioradialis to the biceps. Naito et al.\(^7\) suggest that

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**FIGURE 1:** A comparison of concentric and eccentric elbow flexion activity. There is significantly greater EMG activation during the concentric phases of the elbow flexion tasks than during the eccentric phases (*p < .05).

**TABLE 2. Comparison of EMG Activity During Forearm Rotation Tasks at 4 Loads**

<table>
<thead>
<tr>
<th>Task</th>
<th>Phase</th>
<th>0 N</th>
<th>9 N</th>
<th>18 N</th>
<th>27 N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td>Pronation to neutral</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Concentric supination</td>
<td>2 3</td>
<td></td>
<td>4 3</td>
<td>5 4</td>
</tr>
<tr>
<td></td>
<td>Eccentric pronation</td>
<td>2 4</td>
<td></td>
<td>3 4</td>
<td>5 3</td>
</tr>
<tr>
<td>Supination to neutral</td>
<td>Concentric pronation</td>
<td>2 4</td>
<td></td>
<td>3 4</td>
<td>7* 5</td>
</tr>
<tr>
<td>Supination to neutral</td>
<td>Eccentric supination</td>
<td>2 3</td>
<td></td>
<td>3 4</td>
<td>7* 5</td>
</tr>
</tbody>
</table>

*Note: The table provides descriptive EMG data from all forearm rotation phases during rotational tasks. All data are reported as percentage of MVIC activity (%). Concentric pronation and eccentric supination phases at 18 and 27 N show significantly greater EMG activity than that of eccentric pronation and concentric supination phases within the same loads. There is no significant difference in EMG activity between rotational tasks at lighter loads.

*Significance is equal to p < .01.
with firing of motorneurons of the brachioradialis, there is a reflex inhibition of the biceps. He also concluded that a motion of pronation/supination while holding elbow flexion requires the flexors to change their activities while keeping constant force in flexion.

In a forearm neutral position, brachioradialis protects the distal radioulnar joint by lifting the radius up off the ulna when carrying an object of great weight. This protects the ulna from a marked bending moment. In terminal pronosupination, firing of brachioradialis dynamically assists in the stability of the distal radioulnar joint from translational motion.

Other examples of the clinical relevance of these findings are as follows. First, we have noticed a high incidence of injuries to the brachioradialis in lifting sports such as rock climbing. This can be explained by the fact that the lifting motion of climbing takes place in a pronated position and involves elbow flexion. A second example is in the transfer of muscles and tendons in secondary reconstruction conditions where there is weak elbow flexion such as in brachial plexus injury and tetraplegia. If there is a pronation contracture, that is, more supination is required, then transfer into biceps is suggested, but if there is a supination contracture, then insertion into brachioradialis would be a better option. Third, as pronation is synergistic with wrist extension and fine finger flexion activities, perhaps brachioradialis to flexor pollicis longus and the radial finger flexors may be desirable. This is seen in group I tetraplegia where brachioradialis is transferred for wrist extension and in group II tetraplegia where it is transferred to flexor pollicis longus.

This research supports previous findings and identifies that the brachioradialis primarily functions as an elbow flexor regardless of forearm position. The brachioradialis appears to function more with pronator muscle actions than with supinator muscle actions as determined by greater EMG activity with motions requiring pronator muscle actions. This information allows us to better understand what will potentially be lost if it is sacrificed for another function in tendon transfer procedures.

REFERENCES


FIGURE 2: This illustration demonstrates a significantly greater EMG activity during an elbow flexion task than during a forearm rotational task (p < .05). EMG activity of the brachioradialis is approximately 2 times greater during the flexion task using a 22 N load when compared with the rotation task using a 27 N load.