# PRONATION-SUPINATION MOMENT ARMS IN THE HUMAN FOREARM

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## ABSTRACT
Muscle moment arms of four muscles contributing to forearm pronation/supination (p/s) were estimated using two separate experimental procedures and, when appropriate, compared to two studies presented in the literature. The moment arms for each muscle were estimated by differentiating the tendon displacement of each muscle with respect to the joint angle of p/s. Moment arms for the Biceps Brachii, Brachioradialis, and Pronator Teres were in some agreement with previously published work, while findings on the Extensor Carpi Radialis Longus need further verification.

## BACKGROUND
The change in muscle length divided by change in the respective joint angle of which the muscles spans equals the moment arm length at a specified position [2]. The moment arm of a muscle is a key parameter that plays a significant role in the contribution of a muscle to joint torque. Our procedure used a cadaver specimen *in situ* to estimate the moment arms of four forearm p/s muscles: Biceps Brachii (BIC), Brachioradialis (BRD), Pronator Teres (PRT), and Extensor Carpi Radialis Longus (ECRL). Moment arms were estimated using both numerical and analytical differentiation from fitted polynomials.

## PROCEDURE
The right upper extremity of an embalmed male cadaver specimen of approximate age of 80 yrs with a 51 centimeter forearm was dissected to expose the forearm muscles. The elbow joint had a flexion/extension (f/e) and p/s range of motion of 100$^{\circ}$ and 80$^{\circ}$, respectively. Humeral head was securely fixed to the test stand with the wrist secured at the opposing end of the fixture which allowed f/e and p/s movement (figure 1). To measure the p/s angle, a rotational potentiometer was secured to a rod which rotated with the forearm through the axis of p/s; which rotated along the axis between the proximal end of the ulna to the third finger respectively. A linear transducer was used to measure muscle length with a wire attached to the insertion point of each muscle and traced back through the line of action of the muscle to the point of origin, at which an eyehook ensured the correct point of orientation (figure 1). The linear transducer applied an average force of 7.5 Newtons and was calibrated with an accuracy of +-0.005 mm. Data from the goniometry and linear transducer were sampled at 1000 Hz.

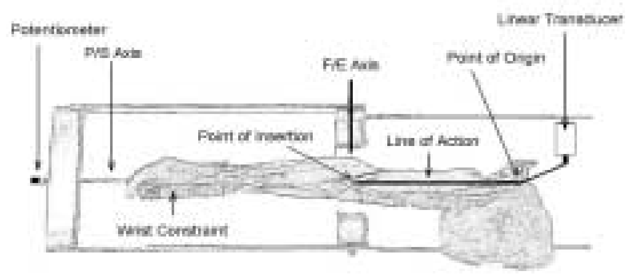


**Figure 1: Cadaver test stand with linear transducer and goniometer.**

Five trials of p/s rotations from the maximum supination position (39$^{\circ}$ from neutral) to the maximum pronation position (25$^{\circ}$ from neutral) for three f/e positions: 15$^{\circ}$, 45$^{\circ}$, and 90$^{\circ}$ where taken. Two experiments were performed using the same protocol, one experiment with intact muscles (*muscle-path experiment*) and a second with the muscles detached from the cadaver (*skeletal-path experiment*). Once data was collected with the intact muscles, the musculotendons were detached from the cadaver specimen, and the second experiment was performed using the same insertion and orientation points, but without the muscle volume. Data from the linear transducer was plotted versus the positional data of the goniometry. Fourth order polynomials were fitted to the function of tendon displacement with respect to p/s angle (R=0.9979) then numerically differentiated with respect to p/s angle to obtain the p/s moment arms. Past studies have used this analytical method more than that of a numerical differentiation of the raw data due to the noise within the analog data.

## RESULTS

Minimal differences were observed between trials, however between each f/e position the moment arm variation in both experiments, respectively, were on average +/-0.16cm and .89cm for the BIC; +/-0.25cm or the PRT; +/-0.23cm and +/-0.02cm for the BRD. Peak values for the BIC and BRD for the skeletal-path experiment were 1.23cm and 0.46cm respectively, which was two to four times that of the muscle-path experiment, 0.28cm and 0.16cm at the same f/e position.

## DISCUSSION & CONCLUSIONS

This study estimated the variation in p/s moment arms in four forearm muscles during forearm rotation comparing the results to literature sources. However, moment arm data was not consistent between various studies, making it difficult for any accurate comparisons [1,2]. The large differences between the muscle-path and skeletal-path moment arms are due to the line of action traced from the linear transducer to the point of insertion. During the muscle-path experiment the muscle cross-sectional area decreases as the muscle lengthens, changing the arch height in the line of action, not the overall length. As a result the skeletal-path experiment was a closer comparison to that of Murray's and Hutchinson's data. In light of the magnitude differences between the various studies, the data did show to follow the same trends found by Murray and Hutchinson. However verification of the ECRL moment arms cannot be shown due to the large differences in our two experiments. Limitations of this study include restricted p/s motion for our specimen and only one specimen evaluated. Further study is needed to verify the current ECRL moment arm magnitudes.

## REFERENCES:


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2. Murray, Wendy M. 1997. The Functional Capacity of the Elbow Muscles: Anatomical Measurements, Computer Modeling, and Anthropometric. Dissertation: Northwestern University, Evanston, Ill, June 1997.

3. Murray, Wendy M., 1995, "Variation of Muscle Moment Arms with Elbow and Forearm Position," J. Biomech, Vol. 28, pp. 513-525.

4. Murray, Wendy M., Buchanan, Thomas S., Delp, Scott L., 2002, "Scaling of Peak Moment Arms of Elbow Muscles with Upper Extremity Bone Dimensions," J. Biomechanics, Vol. 35, pp. 19-26.


| | 15 Degrees | Range (+ -) | 45 Degrees | Range (+ -) | 90 Degrees | Range (+ -) |
|---|---|---|---|---|---|---|
| Bicep Brachii | **0.28** | 0.04 | **0.44** | 0.07 | **0.28** | 0.03 |
| Pronator | **0.70** | 0.47 | **N/A** | N/A | **N/A** | N/A |
| Brachioradialis | **0.39** | 0.06 | **0.16** | 0.15 | **0.33** | 0.02 |
| ECRL | **N/A** | N/A | **N/A** | N/A | **N/A** | N/A |

**Table 1: Muscle-path Experiment Peak Moment Arms, in centimeters, for three f/e positions.**

| | 15 Degrees | Range (+ -) | 45 Degrees | Range (+ -) | 90 Degrees | Range (+ -) |
|---|---|---|---|---|---|---|
| Bicep Brachii | **0.34** | 0.02 | **0.75** | 0.07 | **1.23** | 0.12 |
| Pronator | **0.76** | 0.09 | **0.55** | 0.02 | **0.51** | 0.39 |
| Brachioradialis | **N/A** | N/A | **0.46** | 0.08 | **0.44** | 0.07 |
| ECRL | **0.38** | 0.17 | **0.13** | 0.02 | **0.31** | 0.12 |

**Table 2: Skeletal-path Experiment peak moment arms, in centimeters, for three f/e positions.**

| | Muscle - Path | Skeletal - Path | Murray | Murray Model | Hutchins model |
|---|---|---|---|---|---|
| BIC | 1.23 | 0.28 | 1.30 | 1.30 | 1.20 |
| PRT | 0.51 | N/A | 0.50 | 1.30 | 2.50 |
| BRD | 0.44 | 0.33 | 0.10 | 1.00 | 0.40 |
| ECRL | 0.31 | N/A | N/A | N/A | N/A |

**Table 3:Comparison with Murray's and Hutchinson's peak moment arms at 90 deg. f/e.**

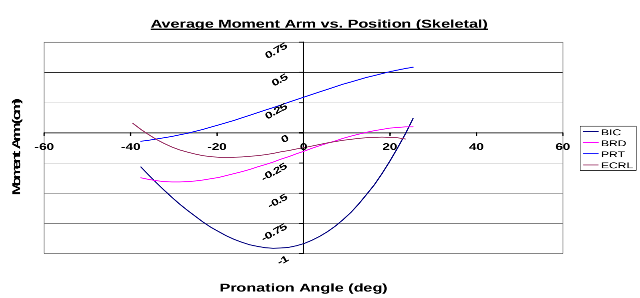


**Figure 2: Moment Arm vs. p/s Position for skeletal-path, pronation position is positive.**