The Relationship Between Muscle Length and Function in the Forearm During Pronosupination

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Introduction: Calculation of joint-relevant forces requires detailed information regarding the active contraction of all pertinent muscles. Although electromyography (EMG) or ultrasound are often first thought of with regard to experimental methods for estimating muscle action, these techniques are less than ideal. An alternative approach using muscle anatomy as the basis for quantifying mechanical function may be feasible. Thus, the objective of this study was to determine if the muscle function that occurs during forearm pronosupination (PS) can be obtained by using anatomical measurements.

Materials and Methods: Ten fresh left upper cadaveric extremities were amputated at the proximal humerus. All soft tissue was removed from the arm except for the ligaments and all soft tissues directly pertaining to the seventeen muscles that control forearm motion, i.e., biceps brachii (BB), brachialis (BRA), brachioradialis (BRAR), supinator (SUP), extensor carpi radialis longus (ECRL), extensor carpi radialis brevis (ECRB), extensor indicis (EI), extensor pollicis longus (EPL), flexor carpi radialis (FCR), palmaris longus (PL), flexor carpi ulnaris (FCU), extensor carpi ulnaris (ECU), abductor pollicis longus at the radial origin (APLR), abductor pollicis longus at the ulnar origin (APLU), pronator teres at the humeral origin (PTH), pronator teres at the ulnar origin (PTU), and the pronator quadratus (PQ). The origin and insertion of each of these muscles was marked with an aluminum rivet which was inserted into the cortical bone. The arms were placed on a custom-made fixture with the elbow flexed (90°) and the distal end of the forearm pointing downwards. The stylus of an electromagnetic tracking system (Motion Star, Ascension Technologies, Burlington, VT, USA) was then used to digitally collect the 3D coordinates of each muscle’s origins and insertions. These data were collected over the entire range of PS motion in 10° increments. The resulting 3D data were then used to calculate the length of the muscle at that forearm rotational position. As a first approximation, it was assumed that all muscle lengths were a straight line from the origin to the insertion and that the effects of muscle wrapping and isotonic contraction were negligible. All muscle length measurements were then normalized to unity by using the longest length observed during PS. Because the specimens had varying degrees of maximal PS rotation, the mean muscle length was calculated when at least five specimens rotated to a specific maximum angle. The resulting range of motion was therefore between 90° of pronation (P90) and 90° of supination (S90). Mean values of normalized muscle length were calculated for each position and then plotted and regressed versus the angle of forearm rotation.

Results: The muscle data are divided into two groups. The first group describes all muscles whose normalized length was below an arbitrarily chosen 96% of the maximum muscle length (Fig. 1). The second group describes all muscles whose normalized length was greater than 96% of the maximum muscle length (Fig. 2). A summary of these trends is shown (Table 1). When rotating from full P to full S, five muscles exhibited a consistent trend of muscle shortening: BB, FCR, PL, FCU, and APLU. Three muscles exhibited consistent lengthening: PTH, PTU, and PQ. Muscles that tended to be longest at neutral (N) were: SUP, ECRB, EI, EPL, ECU, and APLU. Muscles that tended to be shortest at N were: BRA, BRAR, and ECRL.

Discussion: The four muscles thought to have the greatest effect on forearm rotation (PT, SUP, BB, PQ) exhibited the largest change in length. In addition, muscles whose role may not have previously been considered (BRA, BRAR, and APL– both sites) exhibit a comparable change in length and their role in PS should be considered. The trend of the BRA suggests that it shortens during P and thus contributes to valgus movement of the distal ulna. The BRAR is shortest at N indicating a role that brings the forearm back to N. Both heads of the APL exhibit decreasing length from N to full S but the Ulna Head decreases during P indicating it may play a key role in forearm function. Thus, the APL can be thought of as two separate muscles and the influence of forearm rotation in de Quervains disease warrants further investigation. Unlike the APL, the two heads of the PT function in similar fashion. Similar trends in the EI and the EPL support them being used in tendon transfer. The ECU shortens by a similar degree in P and S presumably acting as a DRUJ stabilizer in both positions. In conclusion, the results of this study show that muscle length can be used as an indicator of qualitative muscle function.

Table 1: Notable Trends Exhibited by Seventeen Muscles During Pronosupination

![Figure 1: Comparison of muscle lengths when muscle length falls below 96% of maximum muscle length as a function of the angle of forearm rotation](image1)

![Figure 2: Comparison of muscle lengths when muscle length is above 96% of maximum muscle length as a function of the angle of forearm rotation](image2)

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