BICEPS BRACHII AND BRACHIALIS CROSS-SECTIONAL AREAS ARE MAJOR DETERMINANTS OF MUSCLE MOMENT ARMS

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INTRODUCTION

Changes in strength are often attributed to changes in muscle morphology and architecture [1-4], in addition to neural adaptations [5]. However, changes in muscle moment arm (MA) as a result of hypertrophy are less described. Sugisaki, et al. [6], Akagi, et al. [7], and Akagi, et al. [8] described the positive correlation between muscle cross-sectional area (CSA) and muscle MA, and Sugisaki, et al. [9] noted a small increase in triceps brachii moment arm following hypertrophy. Therefore, the purpose of this paper is to develop a two-dimensional mathematical model to describe how changes in muscle architecture of the biceps brachii (BIC) and brachialis (BRA) may influence the MA of each muscle.

METHODS

A position-elbow flexor anatomical CSA (ACSA) hyperbolic cosine regression equation was extrapolated from West, et al. [10], wherein an MRI was taken with the elbow in extension and a neutral radioulnar joint position.

The radius of the proximal elbow flexors was assumed to be the average of the muscle group's force vector field. A coefficient was applied to all equations to represent the degree of hypertrophy (or atrophy) from baseline, which assumes uniform growth.

A tangent line was calculated to represent the distal BIC and BRA tendons, which originated from the distal-most section of each muscle belly. Because the original hyperbolic cosine regression equation was representative of both the BIC and BRA, it was assumed that both muscles had equal ACSAs, and that the BIC lay directly superficial to the BRA. Previous research has described the similar sizes of the BIC and BRA [3].

The muscle belly of the BIC was set to begin 1.1 cm proximal to the joint center in order to control for insertion point, which was fixed 4.51 cm distal to the axis of rotation (capitulum). This was assumed to be about where the center of the insertion site is, as the capitulum has a 10.6 mm radius [11], the bicipital tuberosity is 25 mm distal from the radial head, and the insertion site is 22 mm long [12].

The muscle belly of the BRA was set to begin 0.69 cm proximal to the joint center in order to control for insertion point, which was fixed 3.17 cm distal to the axis of rotation (trochlea). Like the BIC, it was assumed that this was the center of the insertion site, as the trochlea has a 7.5 mm radius [13], the coronoid process is about 11.0 mm from the trochlea, and the insertion site is about 26.3 mm long [14].

The joint center of the elbow was represented by the origin (0,0), and the perpendicular distance from the tendon to the joint center was then calculated as the MA.

RESULTS AND DISCUSSION

The hyperbolic cosine regression equation showed a strong correlation with the length-ACSA relationship described by West, et al. [10] ($p < 0.001$; $r = 0.911$). The calculated MAs of the BIC and BRA were within previously reported ranges [15] (Figure 1).
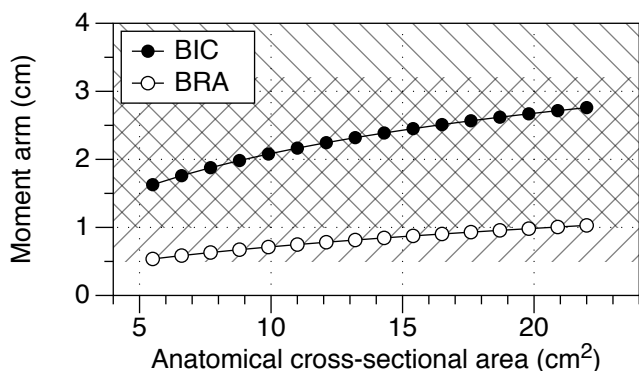
Figure 1: Relationship between biceps brachii anatomical cross-sectional area and muscle moment arm. Negatively sloped lines are normal BIC MAs, and positively sloped lines are normal BRA MAs [15].

To the authors' knowledge, this is the first model to describe the effects of muscle hypertrophy on MA length, which demonstrated remarkable changes in MA of the BIC and BRA with increases in ACSA. Previous research has only attributed increases in torque production to the effects of hypertrophy on muscle force [2, 3], while ignoring potential changes in MA, as described by our model.

Intuitively, this change in MA is a function of the change in insertion angle, as the insertion point cannot shift. This increase in insertion angle occurs when the size of the muscle belly increases, thus shifting the muscle's resultant vector further from the humerus and joint center (Figure 2).
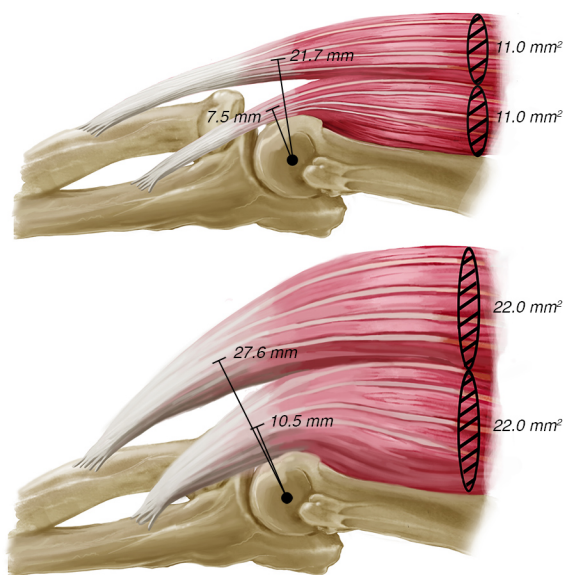

Figure 2: Illustration of the changes in BIC and BRA MAs with increases in ACSA.

The modeled change in MA is proportional to the square root of the change in ACSA ($\Delta MA \propto \sqrt{\Delta ACSA}$). Coincidentally, a similar relationship was observed by Sugisaki, et al. [9], wherein a 33.6% increase in triceps brachii ACSA was accompanied by a 5.5% increase in MA, although the authors did not note this mathematical relationship. More training studies are warranted to examine both the validity of this model and the hypothesis that changes in BIC and BRA MAs are proportional to the square root of changes in ACSA.

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