

15.19 Optional: Neuromuscular biomechanics: Muscle tensions for curling

$$\vec{M}_z = \vec{0} \quad \vec{M}_z = \mathbf{I}_{zz} \vec{\alpha}$$

statics 2D

• Referring to Section 19.6, verify the scalar equation corresponding to a static pose with $q_B = 90^\circ$.

Result: $0.04896 T_{\text{Biceps}} + 0.02320 T_{\text{Brachialis}} = 37.854$

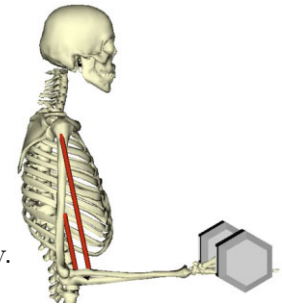
• Calculate the biceps and brachialis moment-arms when $q_B = 90^\circ$.

Result: Biceps = 4.896 cm Brachialis = \quad cm

• Verify the results for the criteria (resolving *indeterminate* forces): biceps only, brachialis only, equal tension, equal stress, and moment-arm ratio.

• **Optional:** † Verify the minimum muscle tension, stress, metabolic energy.

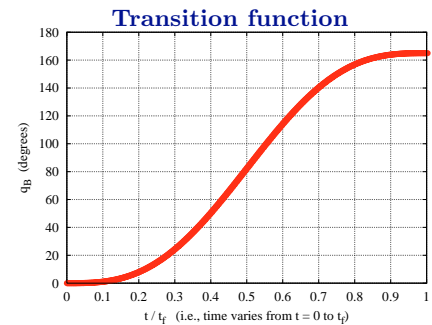
• **Optional:** †† Verify the results that minimize muscle activation.



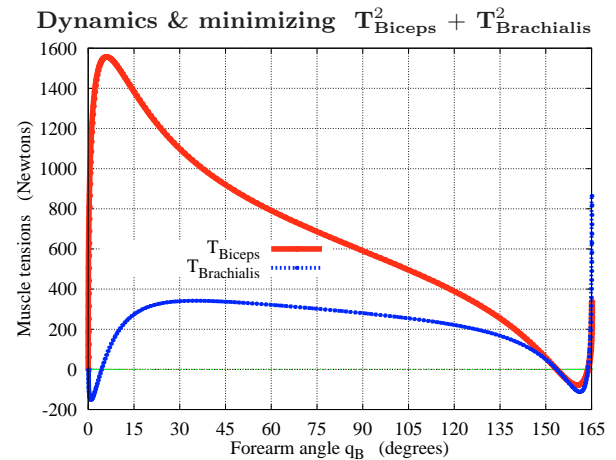
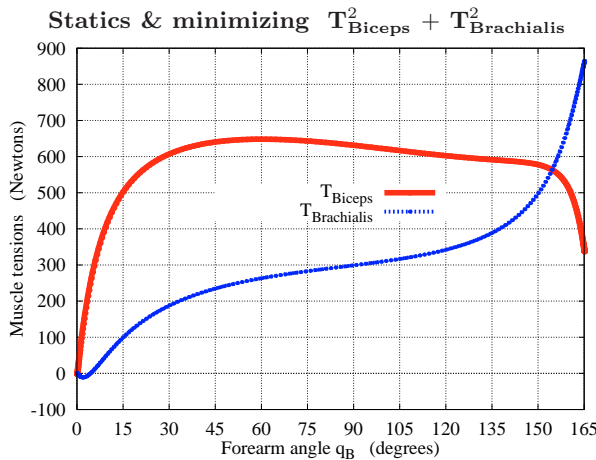
• **Optional:** Consider the criteria that minimizes the sum-square of muscle tensions. Plot the **static solution** for the biceps tension for $0^\circ \leq q_B \leq 165^\circ$.

Repeat for the **dynamic solution** when $q_B(t)$ is the following **transition function**^a from $q_B(0) = 0^\circ$ to $q_B(t_f) = 165^\circ$.

$$q_B(t) = q_B(0) + t \frac{q_B(t_f) - q_B(0)}{t_f} + \frac{q_B(t_f) - q_B(0)}{2\pi} \sin\left(\frac{2\pi t}{t_f}\right)$$



^aThe 1st and 2nd time-derivative of this transition function are zero at both $t = 0$ and $t = t_f$. The function attains its minimum and maximum values at end-points. Large t_f (e.g., $t_f = 20$ min) produces a quasi-static solution.



The results show the biceps dominate curling for physiologically feasible angles ($q_B \leq 150^\circ$). The results also show **negative** brachialis tension which violates the condition that muscles can pull not push (part of these results are unrealistic). Various ways to modify this analysis include:

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| Adding <i>triceps</i> muscles | Optimizing with inequality constraints | Trying a different cost function |
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Section 19.6 and Hw 15.19 solutions at www.MotionGenesis.com ⇒ [Get Started](#) ⇒ [Biomechanics Curling](#).