

15.14 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:**  $0.04896 T_{\text{Biceps}} + 0.02320 T_{\text{Brachialis}} = 37.854$

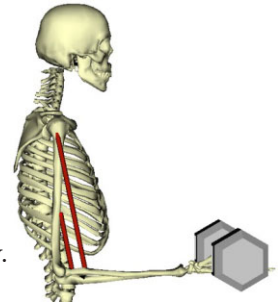
• Calculate the biceps and brachialis moment-arms when  $q_B = 90^\circ$ .

**Result:** Biceps =  $4.896$  cm      Brachialis =  $2.320$  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.

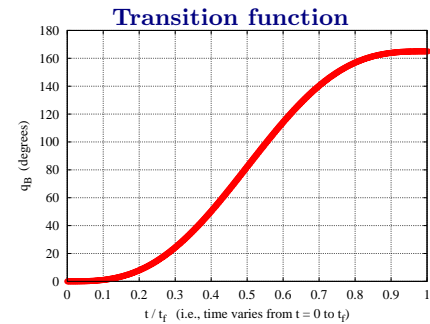
• **Optional:** †† Verify the results that minimize muscle activation.



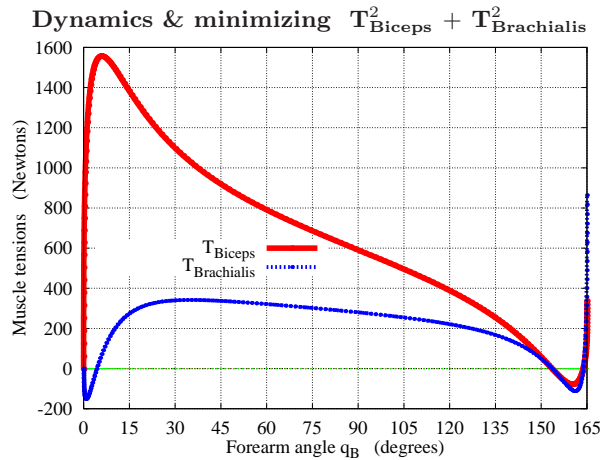
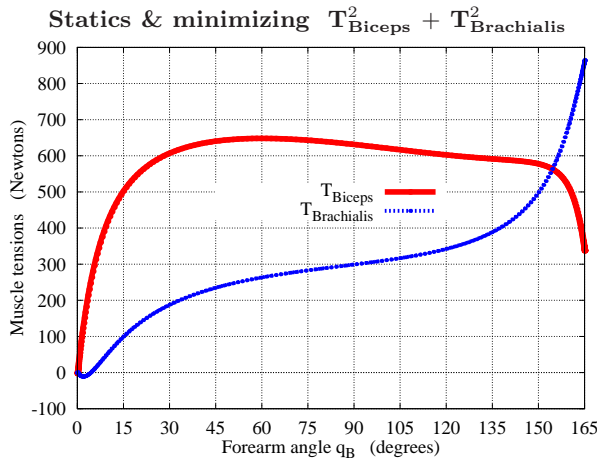
• **Optional:** Consider the criteria that minimizes the sum-square of muscle tensions. Plot the **static solution** for the biceps tension for  $0^\circ \leq q_B \leq 165^\circ$ .

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

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



<sup>a</sup>The 1<sup>st</sup> and 2<sup>nd</sup> 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:

- Adding *triceps* muscles
- Optimizing with inequality constraints
- Trying a different cost function

Section 19.6 and Hw 15.14 solutions at [www.MotionGenesis.com](http://www.MotionGenesis.com) ⇒ [Get Started](#) ⇒ **Biomechanics Curling**.