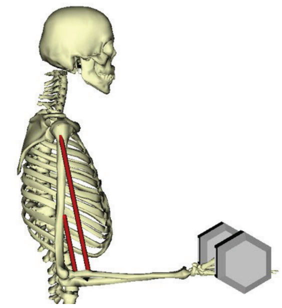
11.14 Optional: Neuromuscular biomechanics: Muscle tensions for curling $\underbrace{\vec{M}_z = \vec{0}}_{\text{statics}} \quad \underbrace{\vec{M}_z = I_{zz}\,\vec{\alpha}}_{\text{2D}}$.

• Referring to Section 17.6, verify the scalar equation corresponding to a static pose with $q_B = 90°$.

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

• Calculate the biceps and brachialis moment-arms when $q_B = 90°$.

Result: Biceps = $\boxed{4.896}$ cm   Brachialis = $\boxed{}$ cm

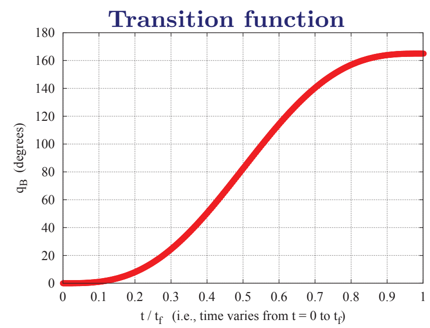


• **Optional:** Verify the results for the criteria (resolving ***indeterminate*** forces): biceps only, brachialis only, equal tension, equal stress, and moment-arm ratio.

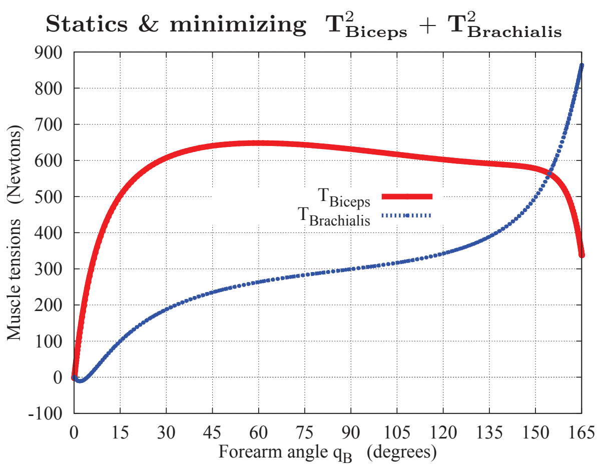
• **Optional:** Verify the results that minimize muscle tension, muscle stress, and metabolic energy, and **†optionally** muscle activation.

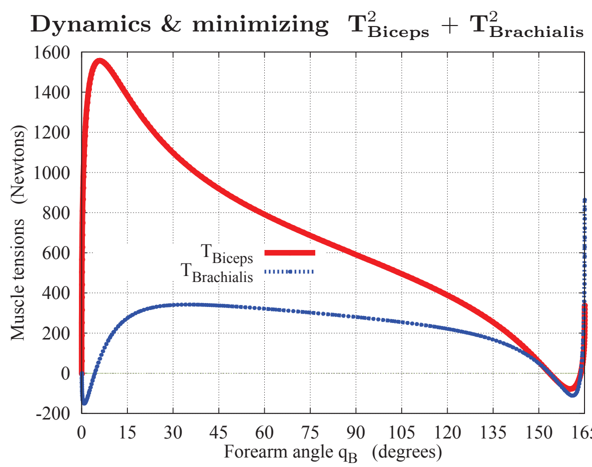
• **Optional:** Consider the criteria that minimizes the sum-square of muscle tensions. Plot the **static solution** for the biceps tension for $0° \leq q_B \leq 165°$.
Repeat for the **dynamic solution** when $q_B(t)$ is the following ***transition function***[a] from $q_B(0) = 0°$ to $q_B(t_f) = 165°$.

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



[a] The 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 ($q_B \leq 150°$). 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 17.6 and Hw 13.14 solutions at **www.MotionGenesis.com** ⇒ **Get Started** ⇒ **Biomechanics Curling**.

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