MCEN 4228/5228
Modeling of Human Movement
(K): Knowledge Problem, (C): Challenge Problem, (EX): Extra Credit
HW03

1. (K) The following equation can be used to calculate muscle fiber force ($F(m)$) at an activation (a), fiber length (l), and fiber velocity (v):

$$F(m) = F_o^M \left(a * f^l\left(\tilde{l}\right) * f^v(\tilde{v}) + f^{pe}\left(\tilde{l}\right) \right)$$

The functions $f^l\left(\tilde{l}\right)$, $f^v(\tilde{v})$ and $f^{pe}\left(\tilde{l}\right)$ represent the normalized active force–length, force–velocity, and passive force–length curves, respectively; and F_o^M represents the maximum isometric muscle force.

How does this equation simplify in each of the following cases?

Muscles fibers are:
(a) isometric
(b) at optimal fiber length
(c) maximally activated
(d) passive

2. (K) "Design" two muscles: one for force and the other for excursion. Each muscle cannot exceed a volume of 600 cm^3. The "Strong"ialis muscle should be able to generate 1800 N of maximum force at one length, and also must be able to generate at least 800 N of force over a range of 5 cm. The "Stretch"ialis muscle should be able to generate 900 N of force of maximum force at one length, and also must be able to generate at least 400 N over a range of 10 cm.

a. Come up with what you think should be the **optimal fiber length** (l_o^M) and **PCSA** of each muscle (assume muscle peak isometric stress, σ_o^m = 0.3 MPa) .

b. Plot the active force-length curve and force-velocity curves for each muscle (i.e., your plots should be in real units, cm for length, cm/s for velocity, and N for force). Use the "normalized" curves that are in the lecture handouts as the basis for your plots. Assume the following normalized force-length and force-velocity equations:

   Force-length: $f^l\left(\tilde{l}\right) = 1 - \left(\frac{\left(\tilde{l}-1\right)}{w}\right)^2$, $w = 0.5$ $and\ \tilde{l}\ is\ normalized\ fiber\ length$: $\left(\frac{l}{l_o}\right)$

   Force-velocity: $f^v(\tilde{v}) = \frac{1-\tilde{v}}{1+\frac{\tilde{v}}{af}}$, $af = 0.25$, $\tilde{v}\ is\ normalized\ velocity$ $\left(\frac{v}{v_{max}}\right)$

   Also, assume the following properties: peak isometric stress, σ_o^m = 0.3 MPa, and v_{max} = 3 l_o^M/s.

   Based on your plots, why do you **think** we have multiple muscles that cross each joint?

c. Plot the power velocity curves for each muscle. Which one generates more power?

3. In the article "*Reducing the energy cost of human walking using an unpowered exoskeleton*" by Collins et al., the authors report a reduction in metabolic cost of walking with use of the exoskeleton. They claim that this reduction in metabolic cost may be due to reduced muscle forces. What evidence do they have to support this?

To Submit Online:

1. ONE homework document as a .pdf: handwritten, scanned or a combination.