Homework 1—Revised

For each of these problems, a brief comparison or discussion is required. No more than a few sentences is needed for each point you wish to make.

1. Do problems 1 through 3 on p. 25 of McMahon.

2. Find the time course of activation (not force) for a muscle receiving a train of excitation twitches, each 2 ms long, occurring at intervals of 2.5 ms. Try two, three, and several twitches in a row. What happens if the separation is even shorter?

3. Compute the appropriate parameters for tendon force as a function of its length:

   \[ F_T = \frac{F}{e^{K_s \Delta t} - 1} \left( e^{K_s \Delta t} - 1 \right) \]

   Find the parameters for a normalized version of this equation, in terms of tendon stress and tendon strain for \( F_T \) and \( \Delta l' \). The exponential curve should be such that at 2% strain, the tendon is at 16 MPa (this typically varies from 5 to 30 in actual tendons). In addition, 2% strain should be the point where the curve interfaces smoothly (continuous first derivative) with a linear region of slope 1.2 GPa (this constrain should help determine the shape parameter). (You should get about 0.874 for the shape parameter.)

4. Try adding muscle excitation dynamics to the kick simulation. What effect does this have on the force trajectory? In particular, what effect does it have on the angular velocity of the leg at the time it reaches full extension (180°)? Use maximum excitation.

5. For the kick simulation with muscle excitation dynamics, find the variation in performance (angular velocity at full extension) as the muscle is varied between slow twitch and fast twitch. Calculate the power produced by the muscle over time for your various simulations. Briefly explain your results. (Let max. shortening velocity vary between about 16 and 4 optimal fiber lengths per second, and activation time between 10 and 30 ms.)

6. Add a tendon (w/ zero pennation) to the quadriceps muscle used in the kick simulation, but for the isometric case with the leg in its initial position. Find an appropriate cross-section area for the tendon such that, when the muscle is producing maximum isometric force, the tendon is at 3.3% strain. Plot the maximum isometric force for this muscle-tendon unit, including a passive muscle element, as a function of length of the entire unit (not including tendon slack length), for a few different values of tendon slack length. How does it differ from the muscle’s force-length curve alone, as tendon slack length increases? Try tendon slack lengths up to 10 times the optimal muscle fiber length.

7. Do a kick simulation for the muscle with tendon at three times optimal muscle fiber length (a typical number for knee muscles). Compare with the simulation without a tendon. Arrange the muscle so that it always remains at optimal fiber length when the leg is in initial position. Place the insertion point of the tendon such that it is at its slack length in this same position. Thus, there is zero muscle force and tendon force when activation is zero. What effect does a long tendon have on the time course of force generation in a muscle? (Since the muscle is shortening from its optimal muscle fiber length, you can neglect passive muscle force in this simulation.)