PME2533 Introdução à Biomecanica
Modelo de Músculo

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Ref.

Winter D., Biomechanics of Motor Control of Human Movement, Wiley Interscience, New York, 1990, chapter 7

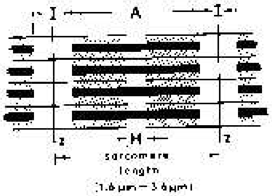

Figure 7.1 Basic structure of the muscle contractile element showing the Z lines [illegible] sarcomere length. Wider dark myosin filament interacts across cross bridges (crosshatched lines) with the narrower actin filament. Darker and lighter bands (A, [illegible] and I) are shown.

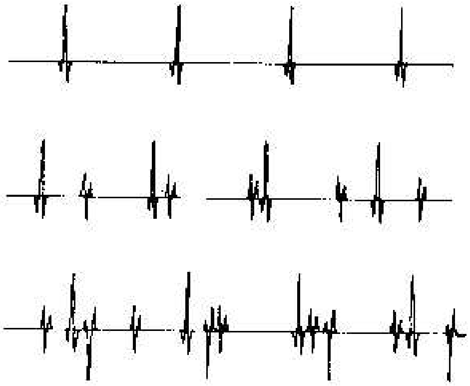

Figure 7.2 EMG from an indwelling electrode in a muscle as it begins to develop tension. The smallest motor unit is first recruited, and as its rate increases, a second, then a third motor unit are recruited. Each motor action potential has a characteristic shape at a given electrode, which depends on the size of the motor unit and the distance from the electrode to the fibers of the motor unit (see Section 8.1.3).

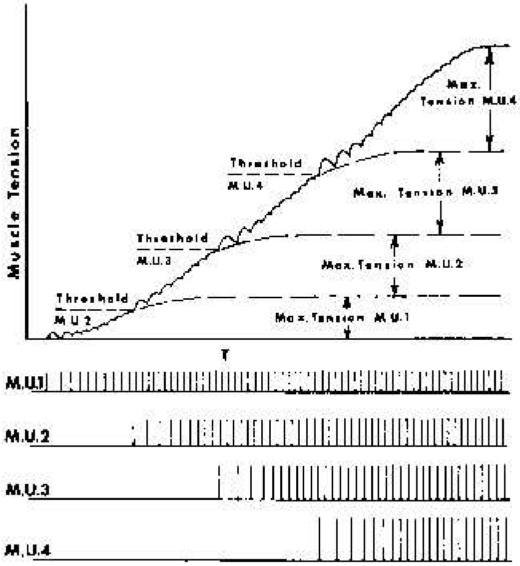

Figure 7.3 Size principle of recruitment of motor units. Smaller motor units are recruited first; successively larger units begin firing at increasing tension levels. In all cases the newly recruited unit fires at a base frequency, then increases to a maximum.

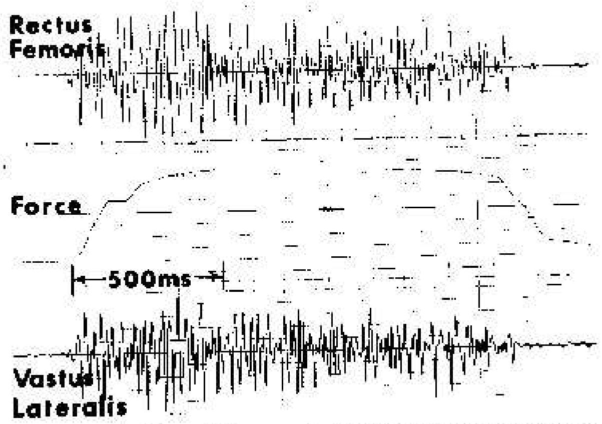

Figure 7.6 Tension buildup and decrease during a rapid maximum voluntary tion and relaxation. The time to peak tension can be 200 ms or longer, mainly of the recruitment according to the size principle and because of delay be motor unit action potential and twitch tension. Note the presence of tension 150 ms after the cessation of EMG activity.

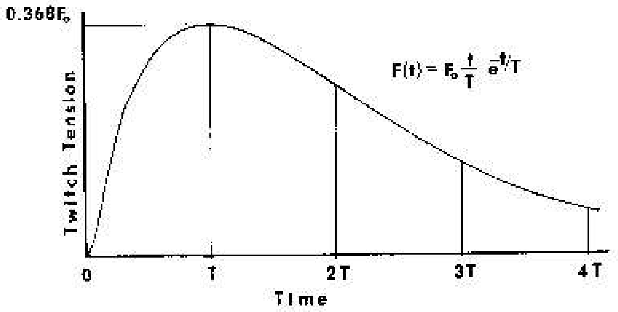

Figure 7.5 Time course of a muscle twitch, modeled as the impulse response of a second-order critically damped system. Contraction time T varies with each motor unit type, from about 20 to 100 ms. Effective tension lasts until about $4T$.

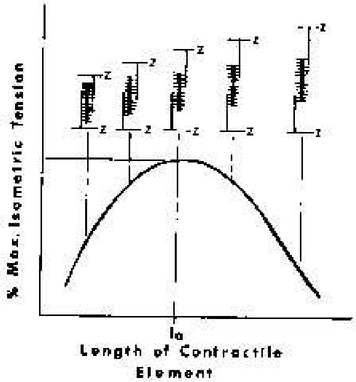

Figure 7.7 Tension produced by a muscle as it changes length about its resting length l_0. Drop of tension on either side of maximum can be explained by interactions of cross-bridge attachments in the contractile elements.

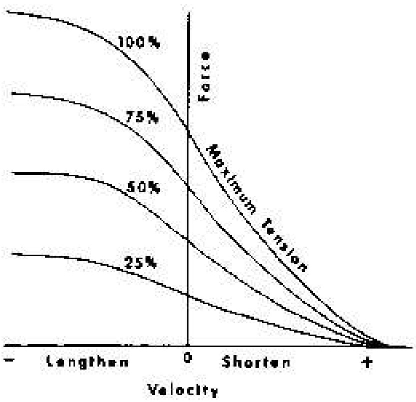

Figure 7.12 Force–velocity characteristics of skeletal muscle, showing a decrease of tension as the muscle shortens and an increase as it lengthens. All such characteristics must be taken as the muscle shortens or lengthens at a given length, and the length must be reported. A family of curves results if different levels of muscle activation are plotted: shown are those curves at 25, 50, 75, and 100% levels of activation.

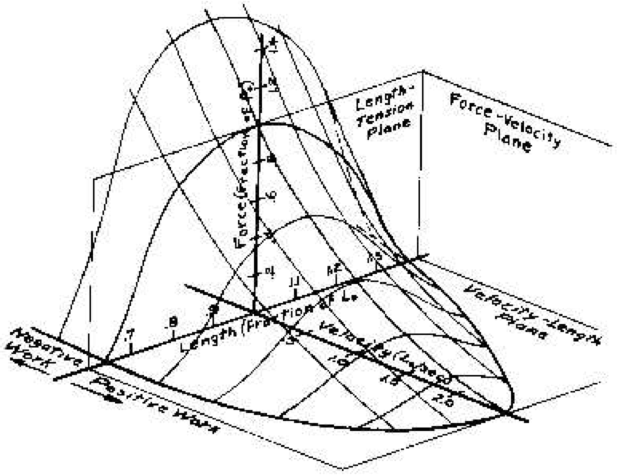

Figure 7.13 Three-dimensional plot showing the change in contractile element tension as a function of both velocity and length. Surface shown is for maximum muscle activation; a new "surface" will be needed to describe each level of activation. Influence of parallel elastic element is not shown.

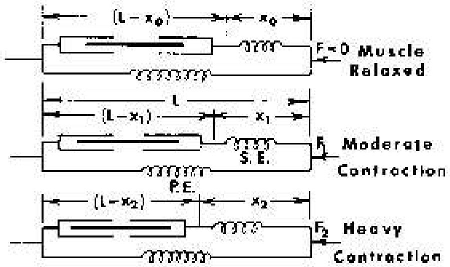

Figure 7.10 Introduction of the series elastic (S.E.) element. During isometric contractions the tendon tension reflects a lengthening of the series element and an internal shortening of the contractile element. During most human movement the presence of the series elastic element is not too significant, but during high-performance movements such as jumping it is responsible for storage of energy as a muscle lengthens immediately prior to rapid shortening.

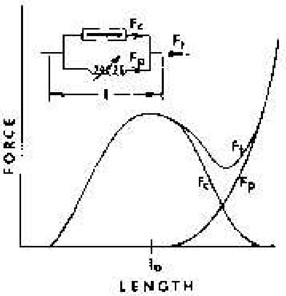

Figure 7.8 Contractile element producing maximum tension F_c along with the tens F_p from the parallel elastic element. Tendon tension is $F_t = F_c + F_p$.

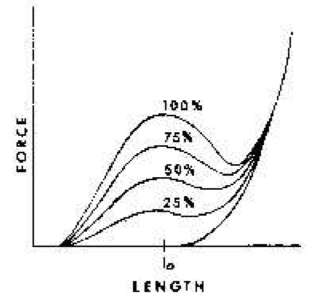

Figure 7.9 Tendon tension resulting from various levels of muscle activation. Parallel elastic element generates tension independent of the activation of the contractile element.

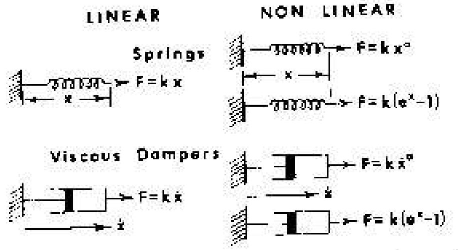

Figure 7.16 Schematic diagram of linear and nonlinear spring and viscous damper elements used to represent passive viscoelastic characteristics of muscle.

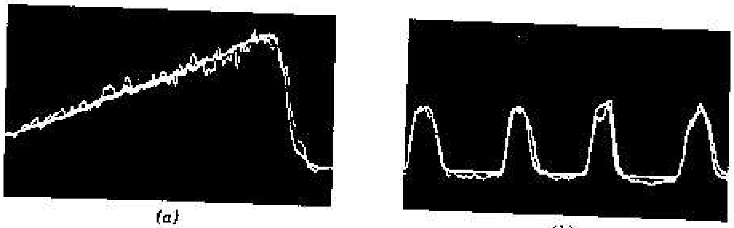
(a) (b)

Figure 7.20 Oscilloscope traces of predicted F_t superimposed on that measured by a force transducer during isometric contractions of the biceps muscle. (a) During a ramp increase of tension. Noisier trace is F_t, smoother trace is the force transducer record. (b) Same model during rapid short bursts of force.

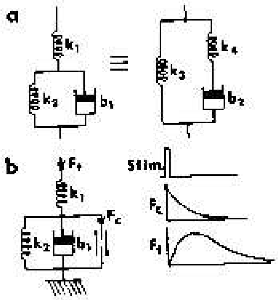

Figure 7.17 (*a*) Two equivalent series/parallel arrangements of linear elements of a muscle model. (*b*) Model showing contractile element acting on viscous elastic elements. Twitch tension of the tendon F_t results only if we assume an exponential activation tension from the contractile element F_c.

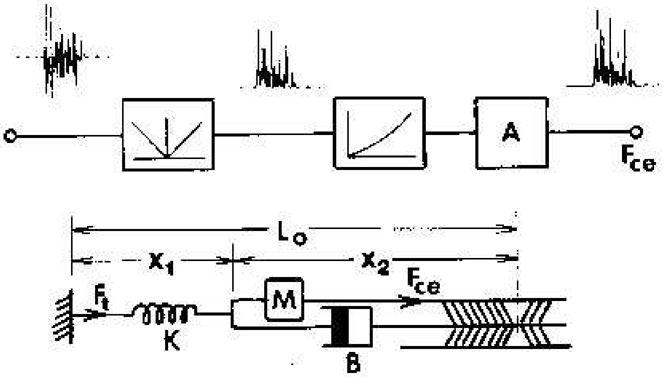

Figure 7.18 Biomechanical model of a muscle during an isometric contraction of varying tension. F_{ce} is modeled as an impulsive contractile element force acting on an equivalent mass M, a linear damping element B, and a series elastic element K. F_{ce} as input to the model is assumed to be the same shape as the full-wave rectified EMG with an empirically curve-fitted nonlinearity. See text for full details and justification for the assumptions.

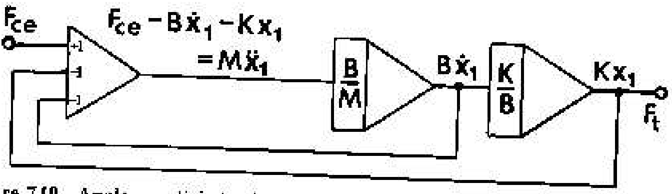

Figure 7.19 Analog or digital solution to solve for tendon force F_t for any given F_{ce} and for any muscle. B/M and K/B ratios are known if the twitch time T for that muscle is known. See text for complete details.