Anatomy
Muscles are Crucial
by Sian Kwa

Muscles are crucial in locomotion

I have been reading the discussion regarding angulation and bone frame in relation to locomotion and speed, with great interest. The main emphasis in this discussion seems to be the skeletal portion of the motor apparatus in dogs and other species. From courses in biomechanics and kinesiology, I always understood that the skeleton has a supportive function to enable an animal to move, but that the muscles with attached tendons, ligaments, aponeuroses, etc. are the actual producers of force, thus speed!!

In the muscle, the muscle fibers are functionally organized into motor units. A motor unit is one nerve fiber attached to multiple muscle fibers. Upon an electrical stimulus of the nerve fiber, all the muscle fibers of the motor unit contract simultaneously. The type of nerve fiber is important in electrical stimulus (myelinated vs unmyelinated), but the bottle neck in speed of transfer of electrical stimulus to the muscle fibers would be the synaptic attachment of nerve fiber to the muscle fibers (=motor endplate). It takes time for the neurotransmitter (usually acetylcholine) to release and be reabsorbed into the presynaptic vesicles. Neuronal feedback about the length of the muscle occurs via proprioceptors in the muscle (muscle spindles) and tendons (Golgi tendon organs). The connection is established in the brain stem. This neuronal feed back system also takes some time, but should generally be similarly fast in similarly sized mammals.

The division of muscles, based on gross anatomy in poulty, into 'white' and 'red' muscles has been obsolete for a large number of years. In 1930, Eccles and Sherrington were one of the first to study motor unit contraction properties, but it is Burke and coworkers in the 70s who connected these contraction properties with histochemical profiles of the muscle fibers in cat motor units. With the crude histochemical methods (enzyme-histochemistry), muscle fibers are already divided generally into:
type I - slow contracting, fatigue-resistant, oxidative fibers
type IIA - fast contracting, fatiguable, oxidative-glycolytic
type IIB - very fast contracting, easily fatigued, glycolytic

The part, which is considered of primary importance for the contraction of a muscle fiber is myosin (actually the heavy chain). Myosin filaments slide over actin filaments (remember your biology classes?). The faster the myosin is able to slide, the faster the muscle fiber is able to contract. With the development of immuno-histochemistry staining methods, more and more different types of myosins are recognized in striated muscles. E.g., Motor units of masticatory muscles contain a myosin, which is previously found only in the heart: cardiac-alpha. This myosin is not found in any other skeletal muscle in the body but the chewing muscles, and not in all species!

Motor units containing this myosin are fast-contracting, but do not easily get fatigued. Guess that's why we -humans- can BS for hours and hours without getting tired (sorry, couldn't resist <G>). Moreover, superfast contracting myosin has been found in feline chewing muscles (not in canids) and with the development of more antibodies for staining, more types of myosin have been found (fetal myosin, embryonic myosin).

In the 80s and 90s, studies have elucidated that -dependent on the task of the muscle (maintaining body posture vs locomotion)- a muscle could consist of predominantly one type of muscle fiber, but most skeletal muscles of the body contain more than one fiber type. E.g. the soleus in mammals (main purpose is to

maintain leg position) has predominantly type I fiber. Gastrocnemius is mixed type IIA and IIB. The muscle fibers in muscles are not static. It has been speculated that in addition to a genetic predisposition toward a specific type, many external and internal factors determine the muscle fiber type. Electrical stimuli (via central nervous system), hormones (gonadal, thyroid), day/night rythms (melatonin production), old age (whatever that is) are a few factors that may induce a change of muscle fiber type.

Estrogen triggers the change of muscle fibers into the slower types. Artificially altered conditions such as stretching the muscle also created a change in muscle fiber type (shift toward the slower fibers).

In other words, in my opinion, more important factors in the production of speed have been overlooked when only discussing the angulations and bone frame of animals. One of the crucial factors is the muscles and the type of muscle fibers. The speed of contraction of the muscles determines the force-velocity curve, therefore the speed of motion of an animal. In addition to muscle fibers and their contractile properties, the organization of a muscle into motor units contribute to the production of force. The larger the motor units, the faster and stronger the muscle. Small motor units are necessary in fine motor control (like hand muscles) for coordination of movement. Large motor units are generally found in leg muscles. Lastly, the anatomy (architecture) of a muscle with tendons and aponeuroses is believed to be important in force production as well. Serial organization of muscle fibers (in parallel muscles) can make the fullest use of the distance between origin and insertion of the muscle. Pennate-fibered muscles have the greatest number of muscle fibers placed parallel between origin and insertion of the muscle. During contraction these muscles shorten less and develop higher forces than parallel-fibered muscles.

This is merely a summary of the complexity of muscles, which may explain the endless discussion regarding the influence of skeletal angulations on locomotion speed.....

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