Jump and run

Energetics and mechanics of explosive and cyclic movements

This thesis is on jumping and running. It’s about fleas, apes, African feet and calf muscles.

Fleas are good jumpers, but why?

The study presented in Chapter 1 shows that small jumpers can use their energy more efficiently than large jumpers. Small jumpers require relatively less energy to raise their body center of mass against gravity before they leave the ground. That is an advantage for fleas.

The study presented in Chapter 2 focuses on jumping ape. It is shown that a bonobo can jump twice as high as a human, even though bonobo legs are less muscular than human legs. It is not technique, however, that accounts for the bonobo’s superior jumping performance. The analysis of their jump shows, that most work is done by the legs during the push-off. How can a bonobo deliver so much work with so little muscle mass? This question remains to be answered, but there are indications that bonobo muscles are stronger that human muscles.

The second half of this thesis is on running. Running is an exhausting activity, for some more so than for others. How is it possible that some runners need less energy per kg of body mass to sustain a certain speed than others?

The study presented in Chapter 3 shows that variations in running economy can largely be explained by the distance at which the Achilles tendon passes by the ankle. During running, the Achilles tendon works like a spring. Energy that is stored in the Achilles tendon during landing can be used during take-off, free of metabolic cost. The more energy a runner can store and reuse in this way, the lower his/her metabolic energy requirements. Model simulations show that more energy is stored during the same movement if the Achilles tendon lies closer to the ankle (smaller moment arm). De model predictions were validated experimentally: runners who have a small Achilles tendon moment arm generally use less energy to run at a given speed.
The study presented in Chapter 4 concerns the question why running requires any energy at all. Can’t we just store and reuse all energy and run without getting exhausted?

Unfortunately not… it is shown that even in a simple task like ankle bouncing energy consumption is higher than during standing. Most likely, the energy is used by the calf muscles in order to generate muscle work that is subsequently dissipated as heat. De human Achilles tendon seems to be too stiff to accommodate the lengthening and shortening of the calf muscle tendon complex and therefore energy production and dissipation by the muscle fibers is inevitable. So why isn’t our Achilles tendon less stiff? Maybe because it is easier to control the position of the foot with a stiffer tendon.