Model-based investigation of neuromuscular adaptation mechanisms with different leg elasticity

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Abstract

In this study we investigate human leg function in long jump takeoff. We are interested to understand how stiffness of the elastic structures influences muscle operation.

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Methods / Approach

During modeling process (Fig. 1) the complex leg structure was simplified to its containing key elements (point mass, muscle model from Häufle et al. (2010), elastic element) along the leg axis to describe leg function (Fig. 2, Fig. 3). To generate an activation signal from sensory input (muscle-length, -velocity, -tension), the model from Geyer et al. (2003) was used as a neuronal reflex model. In order to identify model parameters and to evaluate model quality, experimental data (kinematic and kinetic) of eight trained athletes were captured.

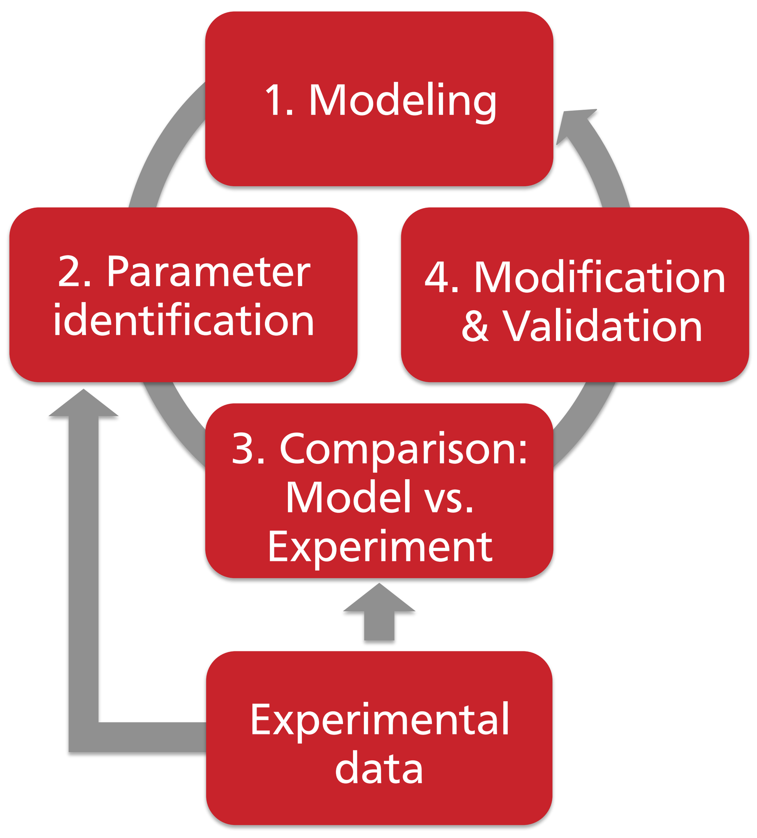

Fig. 1: modeling process

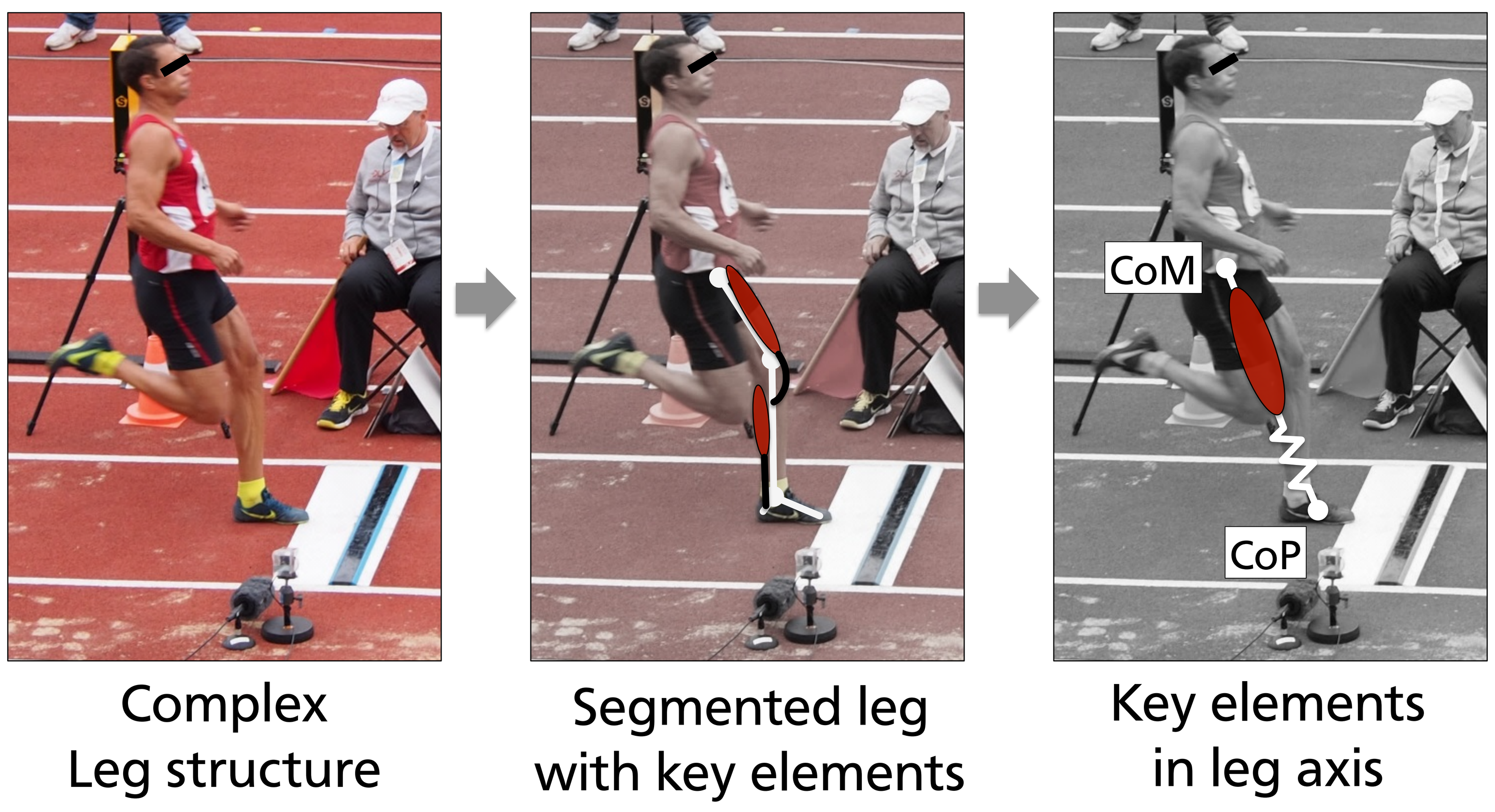

Fig. 2: Simplification process of model

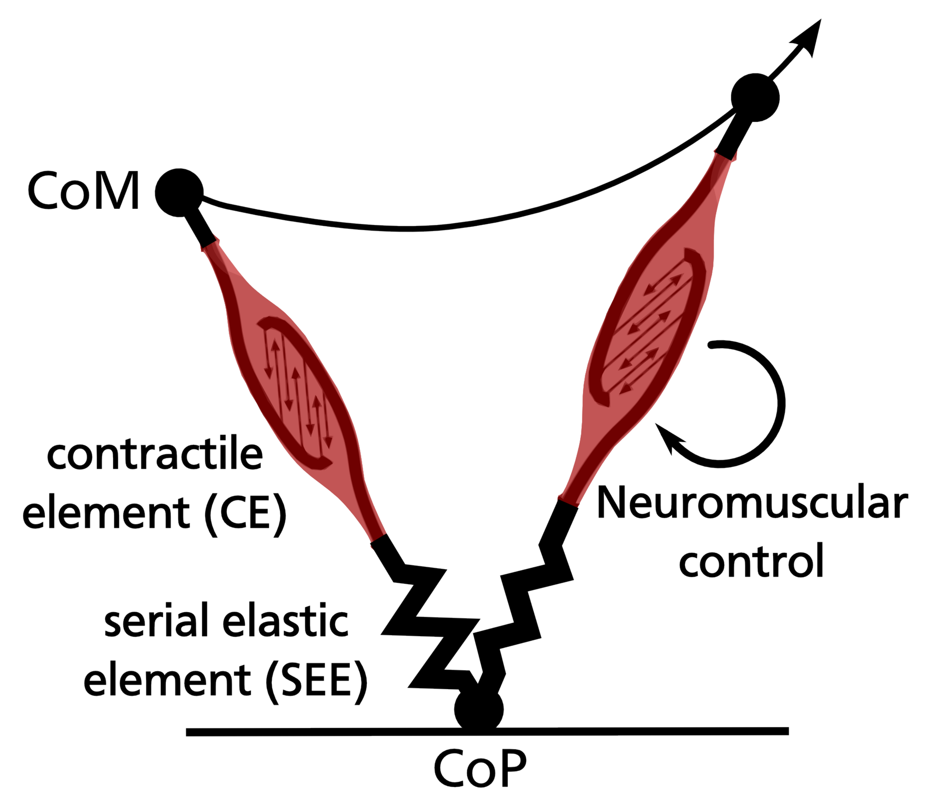

Fig. 3: Long jump model at touchdown (left) and takeoff (right)

Results

The best match of ground-reaction-forces of the optimization (Fig. 4) is found with a serial stiffness of 90 kN/m. Here, interaction dynamics are found to be similar compared to the investigation of a segmented leg from Seyfarth et al. (2000). A comparison of the force-leg length relationship with a SEE stiffness of 25 kN/m shows a changed work loop (Fig. 5). A more compliant serial elastic element (SEE) requires higher activations signals to compensate for a reduced eccentric force enhancement due to a reduced eccentric operation of the contractile element (CE) (Fig. 6). Supporting this, an experimental study of Moritz and Farley (2005) found increased leg extensor activation signals for hopping with decreased ground stiffness.

Conclusion

Interactions between a muscle and an elastic element during takeoff of the long jump were described by a parsimony simulation model which involves a neuromuscular reflex model. The serial stiffness influences the operating point of the muscle and therefore long jump performance. Further studies will focus on identifying optimal mechanical properties to improve long jump performance.

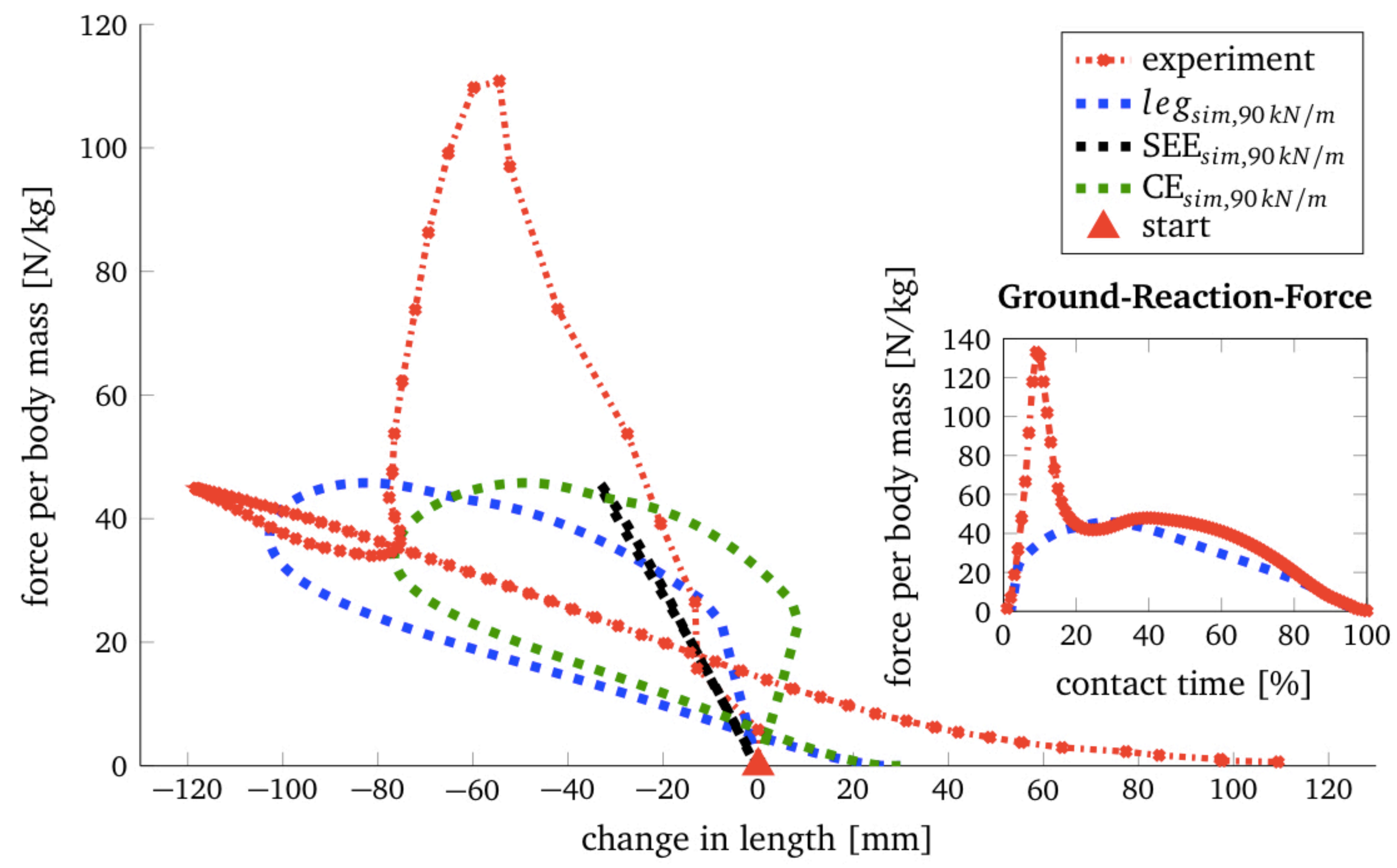

Fig. 4: Force – leg length relationship (left) and GRF (right)

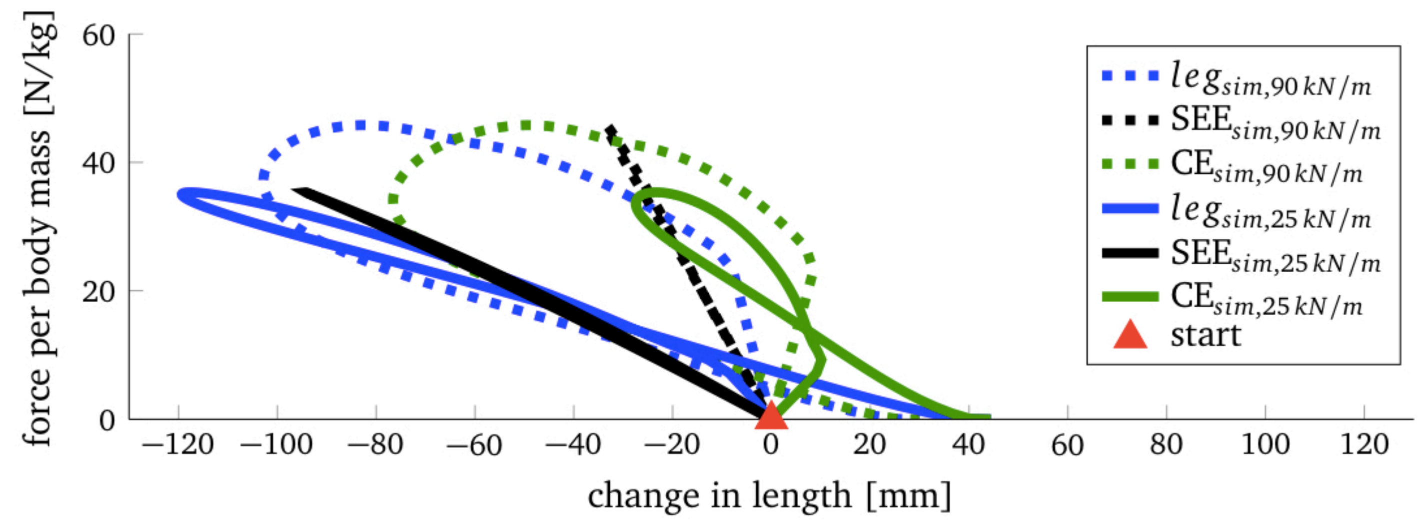

Fig. 5: Comparison of force – leg length relationships with a SEE stiffness of 90 kN/m and 25 kN/m

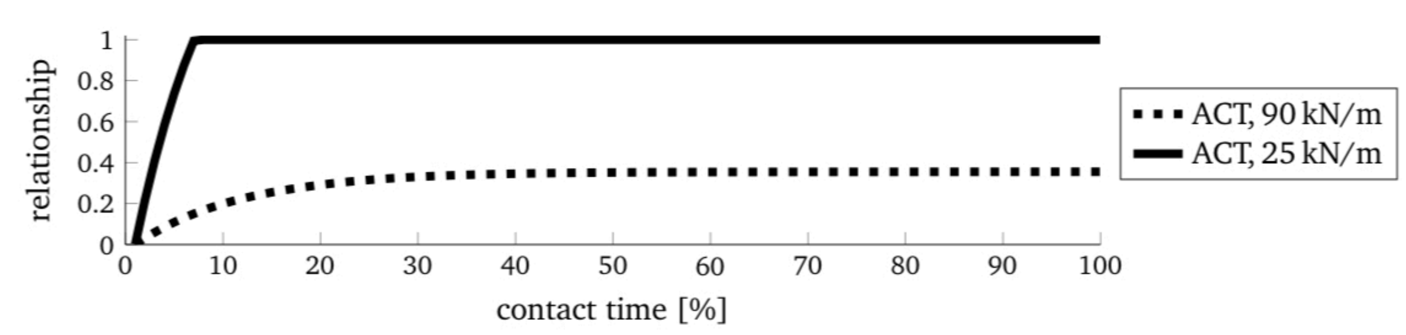

Fig. 6: Activation signal generated by neuromuscular model

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