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IDENTIFICATION OF NEUROMECHANICAL MUSCLE PROPERTIES

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ABSTRACT

In sports science, the importance of computer simulations of human movements has increased in the last few years. There are many mathematical models and simulation programs for movements. A crucial problem in calculating the solution of the model equations for some movement is to find the correct values of the input parameters of the equations, for example, muscle and tendon properties. In most cases one uses mean values stated in the literature. Sometimes these values are scaled to the body height or other anthropometric quantities which can be easily measured. In order to predict movements individually the knowledge of individual muscle parameter values is necessary. We present a method to non-invasively determine neuromuscular properties of the knee extensor model muscle using nonlinear parameter identification, and we give examples of applications like determining muscle efficiency or fibre distribution.

Methods and Results

12 subjects (9 male, 3 female, mass = 71.3 ± 9.2 kg, height = 1.79 ± 0.08 m, age = 23.3 ± 1.7 years) performed 2 isometric and 4 concentric knee extension movements on an inclined leg press (24^o) pushing different loads with maximum voluntary effort (MVC). We measured the force, as well as the velocity and position of the pushed object. A Hill-type muscle model including the activation of the muscle and the geometry of the musculoskeletal system is used to simulate the measured movement (Siebert et al. 2007). While some model parameters are measured directly (e.g., mass, anthropometry) the parameters describing muscle properties and neural activation are determined by nonlinear parameter identification using a modified Levenberg-Marquardt algorithm (Siebert et al., 2007). Fig. 1 shows the hyperbolic force(f)-velocity(v)-relation in the model muscle using Hill's equation $f = c/(v+b)-a$, where a,b,and c are muscle properties determined for different subjects. In Fig. 2, the relation between b_n, defined as Hill's parameter b normalized to the muscle length, and the ratio a/f_{iso}, which describes the shape of the force-velocity-relation, is plotted, $f_{iso} = c/b-a$ denoting the isometric force.

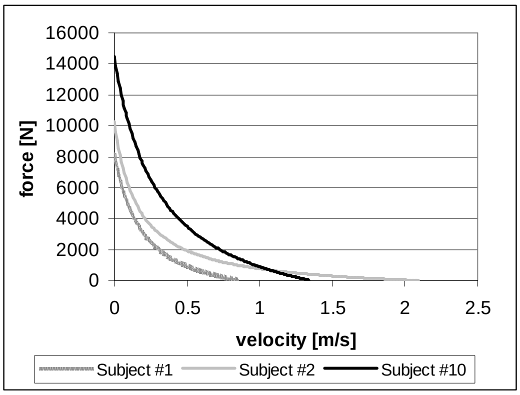

Fig. 1: Force-velocity-relation of the knee extensor model muscle of three subjects

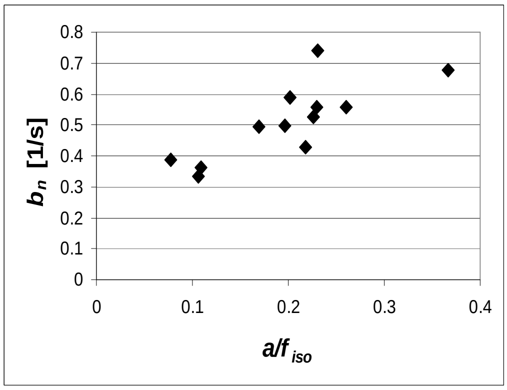

Fig. 2: Relation between the muscle parameters a/f_{iso} and b_n

Conclusions

Figures 1 and 2 show the variation in the muscle parameter values for different subjects. The ratio a/f_{iso}, related to the curvature of the force-velocity-relation in the muscle (Fig.1), is often regarded as constant (e.g.Zatsiorsky 1995). On the other hand, this ratio is higher for athletes in power sports and lower for beginners and endurance athletes (e.g., Zatsiorsky 1995, Thaller and Wagner 2004). Therefore, when using muscle properties as input parameters for models of human movements it is necessary to use individual parameters in order to not lose information on the endurance capacity of the muscle. The second example of an important parameter is b_n. This parameter value correlates to the fibre distribution in the muscle: larger values of b_n are related to the amount of fast twitch fibres (Sust et al., 1997). The determination of the muscle parameters enables to estimate the fibre distribution non-invasively.

By using individual neuromechanical muscle properties as input parameters in models of human movements, we can identify individual performance determining parameters. As is known to trainers in sports science, an increase in muscle force does not necessarily lead to an improvement of performance. Simulations showed that the influence of a change in parameter values on the sports performance (e.g., jumping height) depends nonlinearily on the values of all other parameters, i.e, on the subject's properties and the conditions of the movement. Sensitivity analysis leads to those properties that should be influenced by training in order to achieve the most improvement in performance.

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