MODELLING OF MUSCLE CONTRACTION OF HUMAN TRICEPS BRACHII

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INTRODUCTION

The performance of the human movement apparatus depends on force development of the muscles and force transfer by the skeletal system. On the basis of mathematical models describing the joint geometry separately the influence of muscle force production and bone lever arms on the movement of extremities was analysed. To obtain information about the muscle contractions in the first instance single joint movements were investigated. In this case muscle forces and velocities can be calculated more precisely than in multi articular movements, where optimization methods are necessary for the estimation of muscle force. The goal of the study was the description of the time course of muscle contraction during simple human movements. In this paper results of investigations of the elbow extension are presented.

METHODOLOGY

The kinematics of the forearm movement was measured with a special test machine (fig.1). The subject was positioned in a way, that the shoulder joint was fixed and the forearm movement was possible with only one degree of freedom (elbow extension or flexion). Isometric forces (fixed elbow angle) and velocity-time courses of concentric movements were obtain.

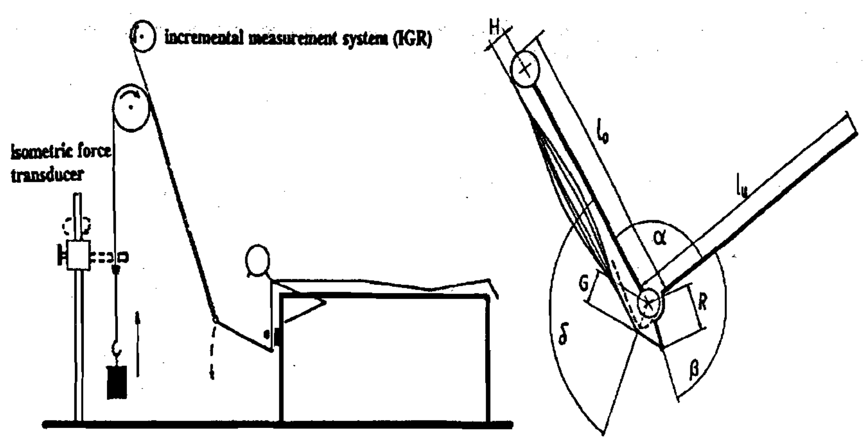

Fig.1: Experimental setup for investigations of the elbow extension and schematic presentation of the anatomical-geometrical model for calculation of triceps muscle force

The velocity of the mass was registered by a high resolution incremental transducer that sends a digital impulse to the computer when a distance of 50æm was converted. The velocity v(t) of the movement was estimated by counting the impulses per sample time of 0.001s. After smoothing the discrete raw data by spline polynoms the distance-time course s(t) and the force-time course F(t) was calculated from v(t).

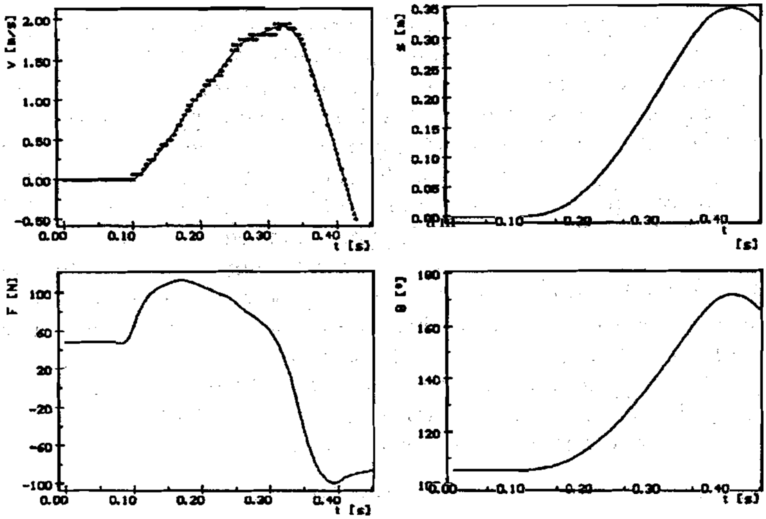

Fig.2: v(t)-raw data and smoothing result, s(t), F(t) of the load and angle-time course Θ(t) of the elbow joint during elbow extension with a load of 5.0kg against gravity

CALCULATIONS AND RESULTS

The kinematic of the load was the basis for the calculation of the angle velocity é(t) and the torque M(t) of the elbow joint utilizing trigonometric relations. With regard to the centre of rotation of the elbow joint and the locations of origins and insertion of the triceps muscle the contraction velocity and the muscle force could be calculated at each instant using a simple anatomical-geometrical model (fig.1). The functions é(t), é(t) and M(t) were converted into lMUSCLE(t), vMUSCLE(t) and FMUSCLE(t) on the base of anatomical data to be measured for each tested subject . The formulas for calculation the locations of origins and insertion (m.triceps brachii) and bone lever arms were derived by evaluation of cadaver investigations.

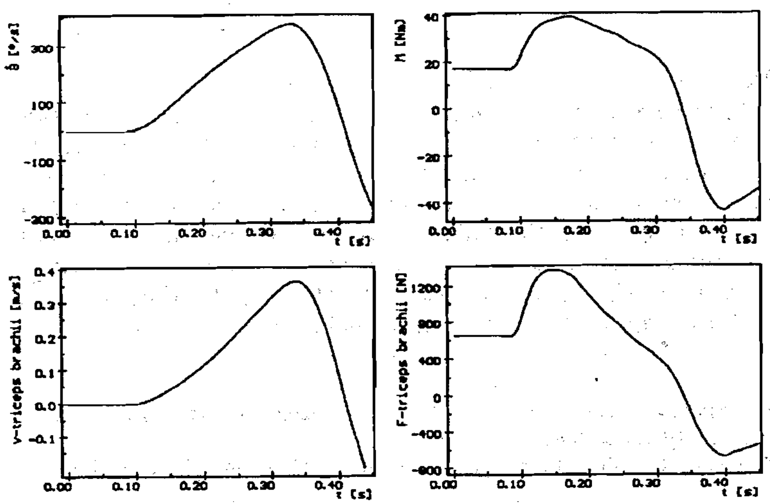

Fig.3: Angle velocity $\dot{\Theta}(t)$ and torque M(t) of the elbow joint and calculated contraction velocity and muscle force of m.triceps brachii during elbow extension with 5.0kg load against gravity (see fig.2)

The modelling of the triceps contraction is based on equations derived from experiments on isolated rabbit muscles (WANK/GUTEWORT 1993). As a result of these investigations and according to HATZE (1981) the contraction course could be subdevided in three processes overlapping each other: activation process (characterized by the velocity of force development), shortening process and process of force decrease due to the increasing overlap of filamanets at the end of contraction. These processes could be described by separate function terms with a modified version of HILL's equation (1938) for description of the shortening process in central position.

The free parameters of the model function are physiologically determind values and represent qualities of the investigated muscle: FMAX - isometric maximum force, S - velocity of force development (initiation velocity), t0 - integration constant, a und b - constants of HILL's equation, Z - strength of force decreasement and lE - muscle length, where no longer force could be developed after shortening. The parameters were estimated by fitting the model function to the calculated F(v(t))-curve of the muscle contraction by the principle of least squares (fig.4).

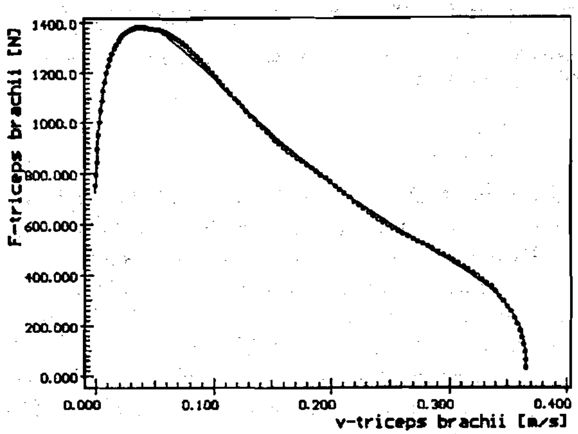

Fig.4: Fitting of the model function to the calculated F(v(t))-course (o) of the contraction of m.triceps brachii

CONCLUSIONS

The course of the human triceps contraction during the elbow extension could be described by the model function derived from animal experiments (see above). Physiological qualities of the tested muscle such as the speed of activation, the absolute maximum contraction velocity and force could be analysed on the basis of the parameter values. In this case the influence of special training methods to the performance of muscle contraction can be estimated.- By comparisons of simulation calculations with the original parameter set and with carefully directed change of parameters the effect of special training methods can be assessed.

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