INTERNAL LOAD ESTIMATION FOR CLINICAL PROGNOSIS

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INTRODUCTION: In therapy and rehabilitation it is important to know the ranges of the expected loads on the human body caused by different movements. The loads caused under these dynamic conditions are estimated by theoretical models and computer simulation because of the difficult measurement of experimental dynamic loads (Bergmann et al., 1993; Bassey et al., 1997). A theoretical model used to estimate internal loads during a squat jump will be presented in this study.

METHODS: A squat jump performed with both legs at maximum strength and without counter movement (Fig. 1) is modeled by a two-dimensional multi-body system with four segments (Fig. 2).

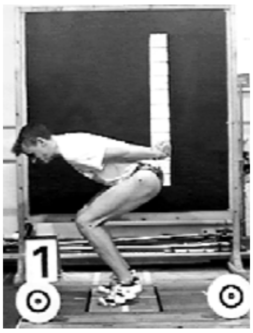

Fig. 1: Initial Position

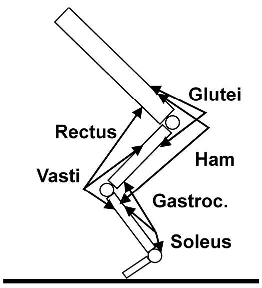

Fig. 2: MBS-Model

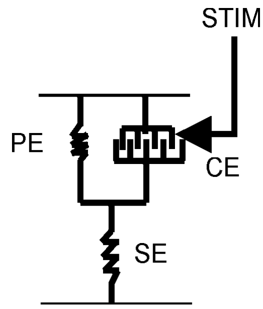

Fig. 3: Muscle model

The movement generating muscles are implemented taking into account muscle insertions and paths, as well as Hill's force-velocity-relation (Fig. 2). The muscle forces are modeled as Hill-type force elements including three components (Fig. 3), the muscle fiber CE in series with the tendon SE and the connective tissue PE in parallel with the muscle fiber CE (as in van Soest, 1992).

The muscle fibers are stimulated (STIM) according to Hatze's stimulation model (Hatze, 1981). In order to incite an explosive reaction, it is necessary to activate in one trial the complete cross section of muscle fibers. To this end the stimulation STIM of the activated muscle must be immediately switched to the maximum. The data of the muscle insertions, paths and properties were extracted from MR images and literature (Subke, 1996).

To obtain maximal jump height the muscles are excited coordinately by optimization algorithms. We apply a parameter permutation algorithm, the Hooke-Jeeves algorithm and the sequential nonlinear quadratic method.
In this way we obtain a movement which is in good agreement with the experimental and simulated data of van Soest (1992) (Fig. 4). For comparison we used the van Soest subject properties (82.2 kg, 1.85 m).

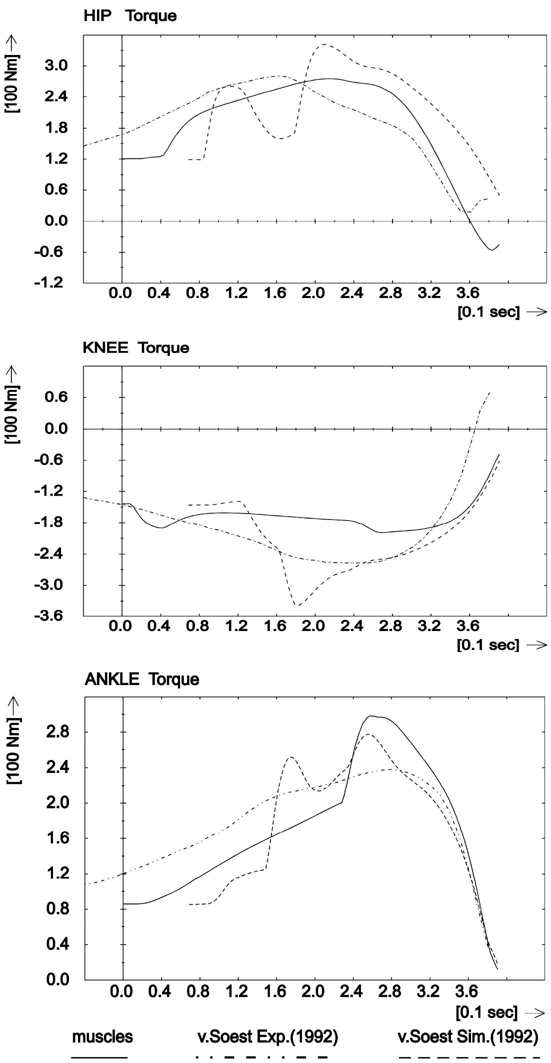

Fig. 4: Torques of the hip, knee and ankle joints

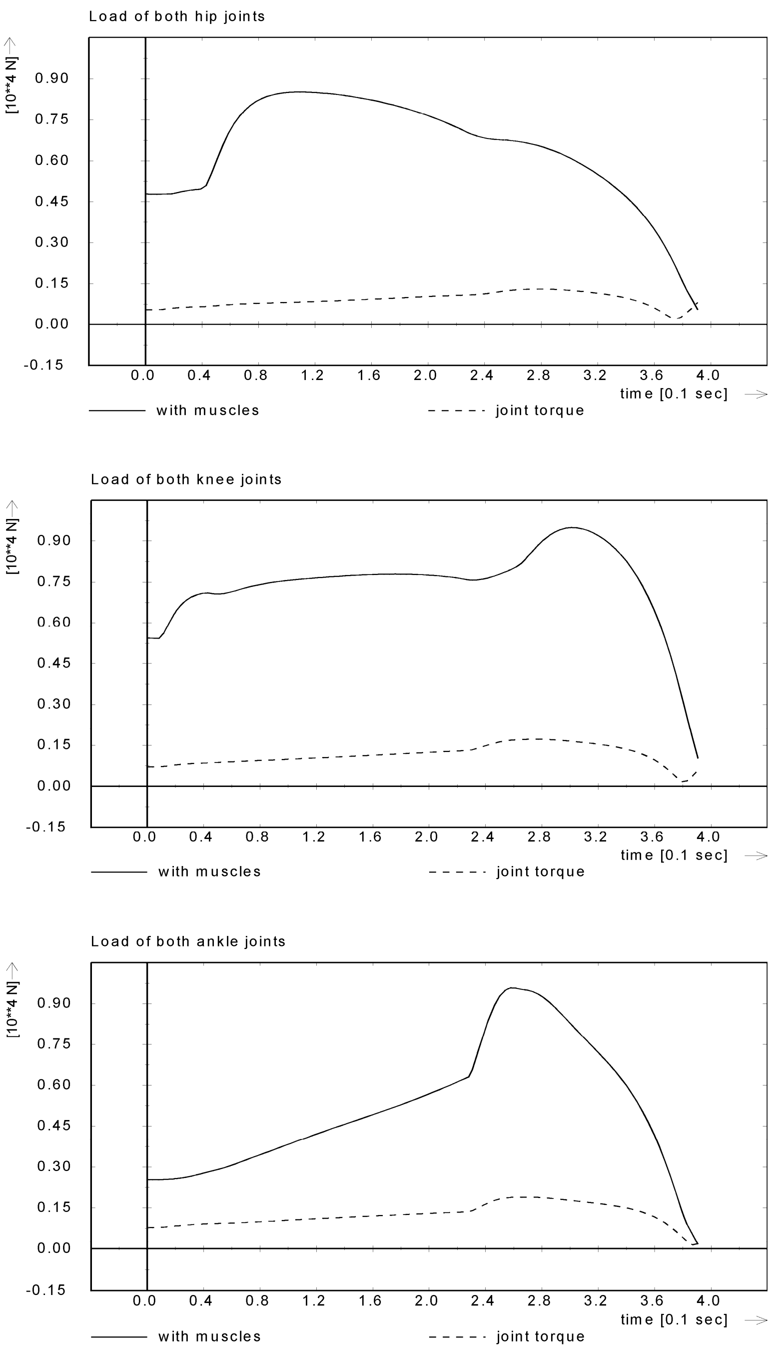

Fig. 5: Loads of the hip, knee and ankle joints

RESULTS: In this case of a vertical jump by a subject (82.2 kg, 1.85 m), the loads (Fig. 5) reach maximum values of 4250 N, 4750 N and 4800 N in the hip, knee and

ankle joints, respectively. The mean values of the hip, knee and ankle joint loads are 3100 N, 3650 N and 2600 N, respectively. Comparing the calculated values with those of Bassey et al. (1997), who measured the hip load during a fast jump, a good agreement of the load values is found.
If we remove the muscle structure and consider only the joint torques the load values decrease dramatically. The maximum values in this case are 650 N, 850 N and 950 N in the hip, knee and ankle joints, respectively. The mean values of the hip, knee and ankle joint loads were 430 N, 550 N and 600 N, respectively.

Muscle	Hip	Knee	Ankle	Torque	Hip	Knee	Ankle
Max. Load	4250 N	4750 N	4800 N		650 N	850 N	950 N
Mean Load	3100 N	3650 N	2600 N		430 N	550 N	600 N

Tab. 1: Load values

CONCLUSION: By means of a vertical jump it is proved that an estimation of joint loads is possible. In order to obtain approximately realistic results it is necessary to integrate the muscle structures into the model. Simple load models usually are not sophisticated enough for the estimation of internal loads (Subke et al., 1997; Subke, 1996). A multitude of movements can be examined with the model on hand in order to compile data for a joint load database which can be used for clinical prognosis.

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