APPLICATION OF THE BRG.LIFEMOD FOR SIMULATIONS OF STEP-MOVEMENTS AND KICKS AND ESTIMATION OF JOINT STRESS

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The purpose of this study was to evaluate a multi body system (BRG.LifeMod) in regard to the application for several simple movements: step-up, kicking movements, step movements. Results of other authors maintain the simulation results. The presented models help to estimate the stress in joints of the lower extremities

KEY WORDS: multi body model, biomechanical modeling, joint stress, step-up, karate kick.

INTRODUCTION:

An important aim of the biomechanical modeling is the estimation of joint stress in order to avoid overload. This is possible by using movement simulations to find the optimal movement exercise. Using better and more powerful computer based techniques, complex multi body models can be created, which enables to simulate sports movements and calculate the joint stress. The purpose of this study is the presentation of models for step-up movements and karate movements to estimate the stress of the lower extremities.

METHOD:

In a first complex a model of the step-up movement with the right leg was created and compared with results from the literature. With this evaluated model the joint stress of the lower extremities was approximated. The second complex focused on two movements from karate, in order to investigate the joint stress of the ankle, knee and hip: mae-geri (front kick) and step movements.

Data Collection: For the step-up movement the height of the stair step amounted 20 cm. The step-up was executed with the right foot. After the contact with the stair the left foot followed. Due to the relatively slow execution the influence of wobbling mass can be neglected (Roemer, 2006). The mae-geri (raising front kick) in the keage form is a snapping front kick with a raising trajectory; the variant considered here is at the chudan level, i.e. middle level, the target being the solar plexus. Step movements mean both-legged jumps in step position with a constant distance between both feet in forward and backward direction. These movements have great importance in the competition kumite (free sparring) to change the distance to the opponent and to achieve the optimal distance for execution a technique with a hit. The full-body human model was created using the software package ADAMS (MSC, Inc.) with its LifeMOD plug-in (BRG, Inc.) and using the Plug-in-gait marker set. For the creation of the complete body the basic model of LifeMOD, composed of 19 segments, was scaled with the individual anthropometrical data of the athlete (karateka with experience in competition, 17 years, 67 kg). To determine the input data and control parameters extensive investigations were necessary: The VICON system (12 cameras MX 13, sample rate of 250 Hz, Nexus V 1.01) provided the kinematical data. The Plug-in-gait marker set permitted the transmission to the model. For the estimation of the cross sectional areas of the leg muscles an open MRI (magnetic resonance imaging) system was used. The MRI raw data were exported in *DICOM* Format and analysed with the software *Osiris* vers. 4.19. For the validation of the muscle model seven knee crossing muscles were recorded by surface electromyography (Biovision company) during the movements. Furthermore a normalisation of the EMG amplitude was carried out on the base of MVC (maximum voluntary contraction). An essential control parameter for the verification of biomechanical models is the ground reaction force. For this purpose a foot pressure measuring system with in-soles sensors (T&T medilogic, Medizintechnik GmbH) was applied.

Modeling: For all specific movements a basic model was created. The adaptation to the specific movement and special conditions resulted from the modification of particular model parameters. After the validation of this model within the simulation the time courses of the joint forces and torques were computed. Figure 2 demonstrates this as an example for the knee. As shown in the diagram the frontal and the transverse components exhibit relative high values. The frontal component which acts as shear force results from the heavy flexion decreases with increasing extension. The basic model (with 19 segments) was scaled by means of the individual anthropometrical data and the database GeBod. Passive trained joints served as bonds between the segments. The muscle base set including 118 muscle elements was added to the model. The next steps of modeling were the *Equilibrium Simulation* and the application of the *Ellipsoid-Plane Algorithm* to define the contact forces between foot and ground (manual of the Life MOD). After this the inverse dynamics simulation was used to train the passive joints and muscles were carried out. For the following direct dynamics simulation the passive elements were replaced by active elements, which take over the control of the movement now. Both simulations run with 100 calculation steps per second. The always procedure of all models was the same. On the base of the control parameters (ground reaction force, trajectories of the feet and hip segments) the results were evaluated to adjust the model parameter. After successful validation of the particular model the joint stresses were estimated.

RESULTS AND DISCUSSION:

First complex: For the step-up movement the comparison between modeled and measured time course of ground reaction force of the right leg shows a sufficient accordance. In contrast, strongly divergent results for the muscle activities have been received. Fig. 1 shows the with the model calculated torque of the hip. Similar results can be found by Bergmann et al. (2001) and Heller et al. (2001).

Second complex: For the kick movement mae-geri it is necessary to distinguish between supporting leg and kicking leg. While the supporting leg is loaded by the body weight the kicking leg is loaded by the acceleration and deceleration during moving and the demanded inertia force. The validation of the model was carried out by the comparison between simulated and measured ground reaction forces. It could be found a relative good accordance (Fig. 3). The mean difference between the trajectories of the inverse dynamics simulation and the direct dynamics simulation amounted 8 mm (kicking foot centre of gravity) and 7 mm (hip). The figure 4 shows the calculated forces and the torques of the knee for both legs. While for the supporting leg the greatest force values occurs at the beginning of the movement (raise of the leg) the knee of the kicking leg has the greatest stress in the stretching phase to reach the target. The high transverse force component of the knee (supporting leg) is remarkable. Furthermore, the step movement was modeled in two variants: uniform and non-uniform. The non-uniform execution is for the competition more important, because of the fast changing of short and large jumps forward and backward. Only in this way it is possible to start the attack or to avoid a hit. Thus for this variant the greatest stresses were found. For special interest is the consideration of the ankle. Table 1 shows the joint forces and torques of both ankles and for both executions.

CONCLUSION:
The presented study discusses some examples with regard to application of multi body systems in biomechanical modeling. For a relative simple movement as the step-up movement a high correctness of the simulation could confirm. A fundamental problem is the configuration of the model parameters. In a first approximation the basic anthropometric and muscle parameters provide sufficient simulation results. Individual adaptations can improve the simulation. With help of these models the stress in various joints could be estimated.

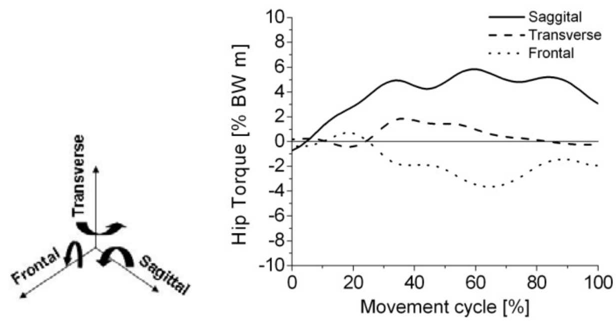

Figure 1: Calculated torque of hip for the step-up movement (complex 1)

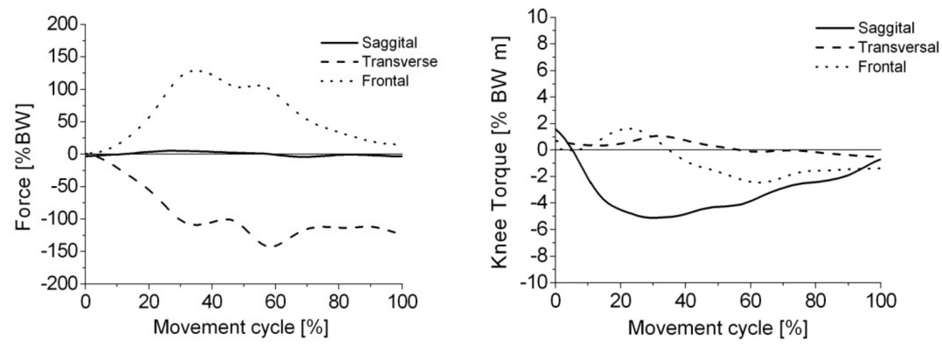

Figure 2: Calculated force and torque of knee for the step-up movement (complex 1)

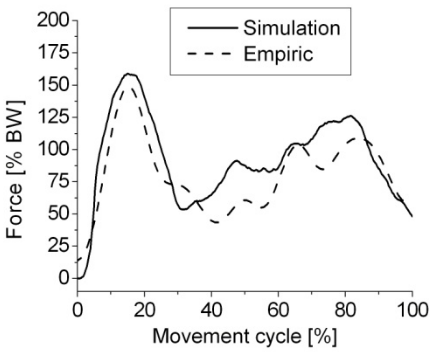

Figure 3: Comparison between simulated and measured contact forces for mae-geri, supporting leg vs. ground (complex 2)

Table 1 Simulated forces and torques (maximum values) of the ankles for uniform and non-uniform step-movements (complex 2)

Ankle	Force [% BW]		Torque [% BWm]	
	uniform	non-uniform	uniform	non-uniform
	sagittal		Sagittal	
left	24	42	52	42
right	17	36	40	49
	transverse		transverse	
left	317	327	5,1	7,2
right	256	328	2,4	6,0
	sagittal		Sagittal	
left	23	50	10	14

right	64	76	8	7,5

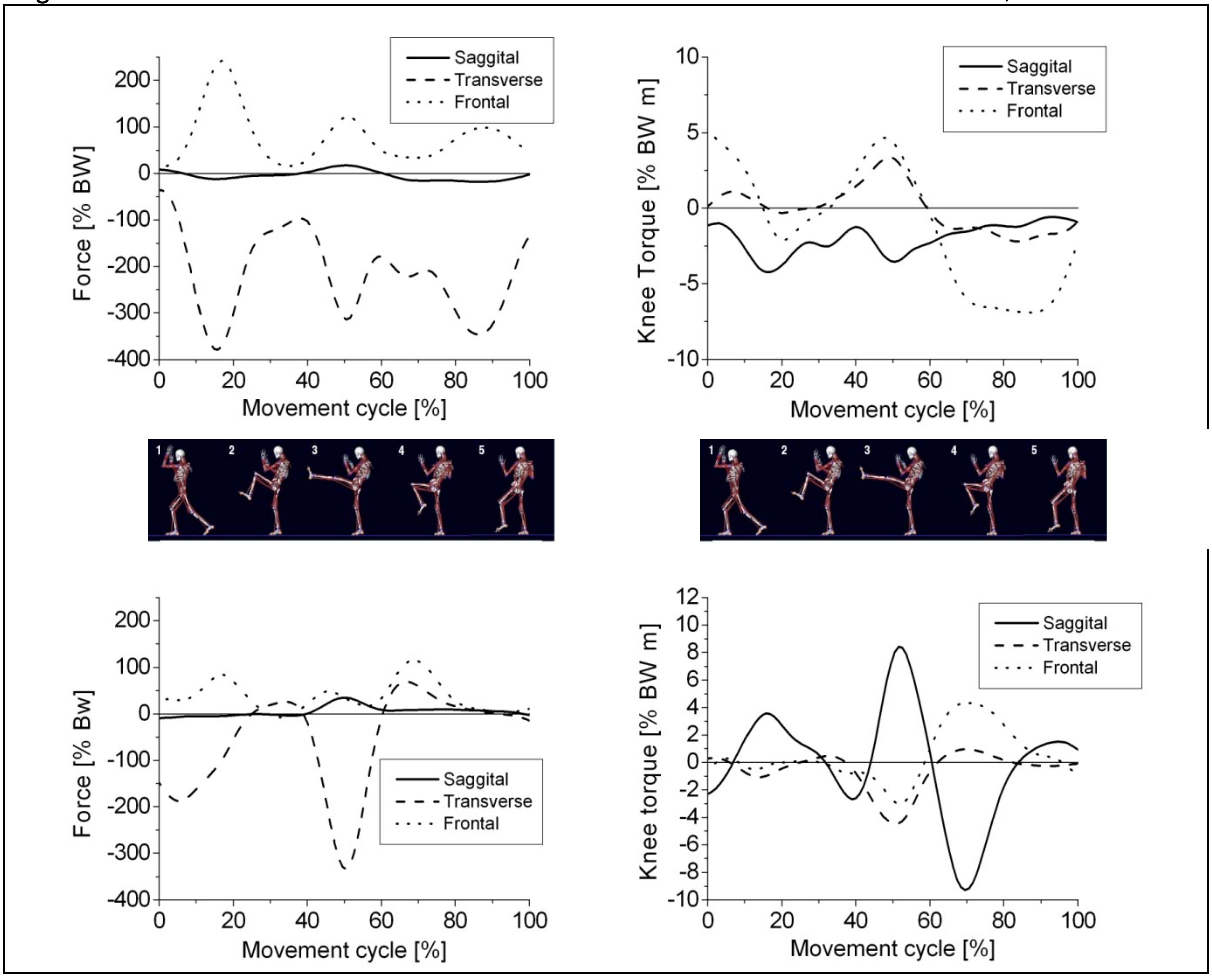

Figure 4: Calculated force and torque of knee for the mae-geri. Upper diagrams: supporting leg, lower diagrams: kicking leg (complex 2)

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