Improving the individual running technique of above knee amputee sprinters by using computer simulations

C. Bohn¹, GB. Shan², T. Korff³, K. Nicol¹
¹University of Muenster, Germany
²University of Lethbridge, Canada
³University of Texas at Austin, USA

Introduction
Investigation of running with prostheses can already be found in literature but mainly for below-knee amputees (Buckley 2000). Most authors are focused on the improvement of the prosthesis itself. In any case gait analysis of walking is predominating. Computer simulation to improve the running patterns of above-knee amputees could not be detected. Therefore, the aim of the present study was to improve the individual sprinting technique of above-knee amputees. Firstly, typical biomechanical parameters which describe the sprinting technique appropriately were defined. Secondly, according to the founded parameters, the influence of these variables on the stride frequency by computer simulation was investigated.

Methods
8 above-knee amputees took part in the study. On average, for each subject three trials were analysed. The experimental set-up allowed synchronised kinematic and dynamic recording up to three successive steps. Two high-speed video cameras (250 Hz) and a segmented 3-dimensional force platform (measuring area 240x80 cm²) were used (figure 1).

In the sagittal plane the following kinematic parameters were analysed: joint-angles, -velocities, -accelerations of hip, knee and foot of both sides of the body. The vertical movement of the center of mass (COM) was calculated from the kinematic data. Swing- and stance phase duration as well as ground reaction forces (dynamic parameters) were obtained.

For simulation a two dimensional model with three segments using DADS 9.0 software was developed, based on the anthropometrical and recorded kinematic parameters (e.g. x- and y-co-ordinates of different joint markers, original knee- and hip angle time course, initial value for knee- and hip angle and angular velocities ) of each subject. In addition hip torque curve was chosen as input variables and as output knee and hip angle curves were shown (figure 2). Swing phases of prosthesis side were simulated.
Results & Discussion
Investigation of the individual running technique of the participants showed non-effective movement patterns in comparison to the sprinting performance of non-amputees, e.g.:

- different swing and stance phase duration of both body sides
- tendency to retard on prosthesis side because of the longitudinal impulses
- wide range of vertical movement of COM up to 25cm. In comparison Mero et al. (1992, 382) showed a maximum vertical range of 6cm in non-amputee sprinting
- high vertical peak force (up to 7 times body weight) and forces rates

The last founded parameters may result in an overload of biological tissues. Especially the swing phase showed a very fast extension of prosthetic knee joint which caused a high moment of inertia at hip joint. Exemplary, fast extension can be seen in figure 3:

According to improvement of the individual running technique we assume that running velocity can be increased by modifying stride frequency. The forward modelling showed that less flexion and more extension net torques at the hip were needed to change hip and knee angle curves to increase the stride frequency and with it the running velocity for all subjects. The calculated net hip torque decreased extension velocity at knee joint and produced less moment of inertia at hip joint on prosthesis side.
At al, the simulations indicate that the variation of the net hip torque can result in better sprint performance. Whether the subjects could not produce the calculated torques due to the muscle weakness or due to deficit inter muscular co-ordination demands on further research.

In order to achieve the calculated smoother and more effective sprint run, additional EMG analysis can give hints, which muscles are needed during the sprinting, depending on the stump length. Adaptational studies should be undertaken to show the mutual influence of both legs, too.

References

Acknowledgements
This study was supported by the „Bundesinstitut für Sportwissenschaft“