ESTIMATION OF SPINAL MOTION AND LOAD FOR HUMAN FULL-BODY MOTION

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INTRODUCTION

Back pain is the second most common reason for chronic pain syndromes [1]. About 60% of all germans complained about back pain in the last years [1]. One factor therefor, besides muscle tensions and sceletal-diseases, can be overload of the spine. In fact there is a lack of studies about the loads between the vertebrae of the spine during human movement. Therefore, the aim of this study is to apply a new coupling between experimental and computational techniques, including a detailed spinal model, and to receive informations about spinal motion and loads during human motion.

METHODS

The computational framework MKD-Tools [2] was designed for the kinematic and dynamic analysis of models with measured data. It is based on a recursive multi-body formalism and allows for the development of arbitrary spatial anthropomorphic models. A constrained nonlinear optimization routine for the transfer of motion capture data to the models is included performing the inverse kinematics. Combining kinematic data with dynamic data from measurements produces dynamic equilibrium equations with residuals. Therefore, a residual reduction algorithm was implemented in order to minimize the appearing residuals while improving inertial parameters and distributing the error over the whole model.

Subject specific models of the full human body were created with 104 dof based on anthropometric data [4] including a detailed model of the spine with 75 dof [3] (Fig. 1). The spinal model allows for the computation of movement and load between pairs of vertebrae without marker information available for each vertebra by approximating the shape of the spine with coupling techniques. The marker set was designed in order to track full-body movements with an IR motion capture system. Inverse dynamics is used in order to compute actuator and constrained forces, and thus, the loads between pairs of vertebrae.

Exemplarily the kinematic and dynamic data of 12 healthy international acting tap dancers, recorded simultaneously with a motion capture system (Vicon, 200Hz) and two force plates (AMTI, 1000Hz), were used for the calculations. Tap dancing includes fast double-support, single-support and flight phases and therefore, it is challenging for the computational routines.

RESULTS AND DISCUSSION

The calculated loads appeared plausible. Due to the fast movement relatively high residual forces appeared before applying the residual minimization algorithm, which was able to reduce the residuals of about 80%. High translational forces usually appear in longitudinal direction (Fig. 2). Detrimental bending moments occur with respect to the translational axes. The model was able to show these curvature dependent moments (Fig. 2). Future research will be extended to models with muscles, ligaments and intervertebral discs in order to consider the additional tension produced from these elements and will include experimental data of human everyday movements.

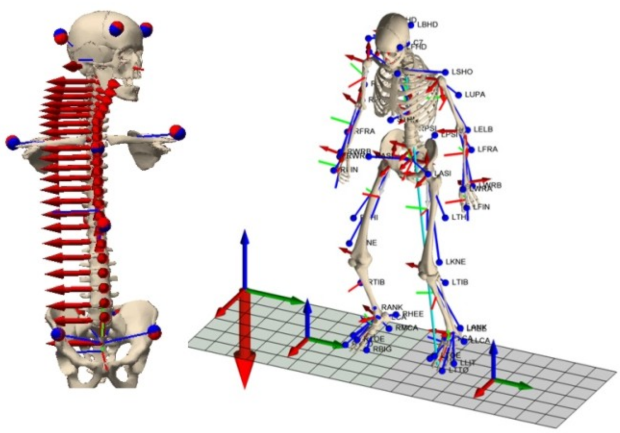

Figure 1: Left: Spinal model with joint axes. Right: Simulation setup, anthropomorphic multi-body model with force plates and markers.

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REFERENCES

1. Diemer W, Burchert H, Gesundheitsberichterstattung des Bundes, Heft 7, Robert-Koch-Institut Berlin, 2002.
2. Stelzner G. *Dissertation*, University Press, University of Karlsruhe, Karlsruhe, Germany, 2008.
3. Simonidis C, et al., IDETC, Las Vegas, DECT2007-35257, 2007.
4. Zatsiorski VM, Human Kinetics Pub Inc, 2002

Figure 2: Results for maximum sagittal, translational and longitudinal force (l.) and torque (r.) between pairs of vertebrae.