NUMERICAL ANALYSIS OF KNEE JOINT AT MAXIMUM POWER TENNIS SERVE

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Abstract

The aim of this paper was to computationally investigate the structural integrity and resistance of a human knee joint at the maximum power tennis serve. The assessment of knee resistance if of high importance in order to tract and evaluate the player's health status and predict the knee injury. The methodology of this paper is based on tracking the knee's kinematics, ground force measurement, inverse dynamics modelling and analysis of the knee using the Finite Element Method (FEM). The applied boundary conditions correspond to maximum loads during the tennis serve. The main aim was to assess the knee resistance of a tennis player, considering acute deformations and potential injuries. The obtained results show a good correlation with stress distribution in real cases. The presented knee joint model and applied methodology are excellent basis for further development of the optimized computational technology and creation of practical diagnostic tool for non-invasive assessment of the knee function during specific moves and motions in tennis.

Key words: Finite Element Method, Knee joint, 3D model, Computational analysis, Prediction of knee injury, Tennis serve

1. Introduction

The serve is the most complex stroke in tennis which requires a synchronized combination of motions in order to transfer all the force from the ground, across the racket up to the hitting the tennis ball. In the case of maximum serving motion very demanding task is to accurately differentiate the forces and torques acting in the human joints, bones, soft tissues and articulation. In this paper we used FE knee joint model to analyze stress distribution in the joint using forces obtained from force plate and inverse dynamics.

2. Materials and Methods

The analysis of mechanical loads on one leg due to the tennis serve was based on kinematic analysis [1]. The applied methodology for 3D analysis of tennis player's motion has been presented in the study of Elliot et al. [2]. The first step was data acquisition of time dependent ground reaction forces and 3D positions of leg joints from force plate and optical motion capture system. The forces and torques in the leg joints were determined using inverse dynamics [3]. Obtained forces and torque were than used to analyze knee joint stress distribution during serving

motion. The FEA was performed on the 3D knee joint model that consisted of bones, cartilage, menisci and ligaments [4].

3. Results and Conclusions

The FEM has found a wide application in the prediction and prevention of the fracture occurrence of the bone tissue, as well as of the soft tissue damage. The numerical simulation of knee model (Figure 1), showed that maximum stress (27.9 MPa) was present in anterior cruciate ligament. Our results support the known fact that ligament rupture is one of the most common injuries related to lower extremities [5].

The future study will include more complex material properties for ligaments and menisci, and more precise results are expected. The main objective of this paper is development of the optimized computational technology and creation of practical diagnostic tool for non-invasive assessment of the knee function during specific moves and motions in tennis. It is expected that this approach can provide prediction and injury prevention in training and competitive tennis to a significant extent.

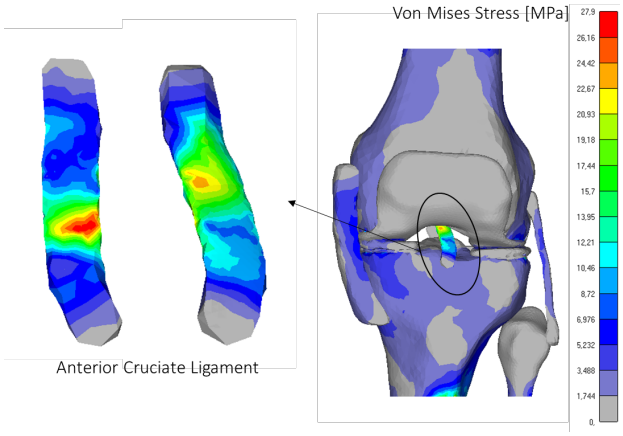

Figure 1. Knee joint model – von Mises stress distribution [MPa].

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