Abstrakt

This scientific work focuses on the creation of a detailed model of the human lower limb using the finite element method (FEM), and on conducting a quasi-static simulation of motion based on a normal gait cycle. The use of an anisotropic constitutive equation to describe the material properties of the bone matrix is a distinctive feature of this work. The result of the simulation is a precise reflection of the physiological state of stress of the right femur and the calculation of its internal state during movement. The conducted analysis of stresses and strains revealed a complex and dynamic internal state that correlates with the microstructure of the bone.

The work began with the creation of a simplified beam model in FEM, based on the Gait2392 project from the OpenSim software, replicating the musculoskeletal system of the right leg. The beam model allowed for the validation of the capabilities and accuracy of mapping functions from OpenSim. In the work, we used the elastic-contractile muscle model by V. Creuillot as an alternative to the complex Thelen model from OpenSim. The elastic-contractile model required determining only the momentary length and force of the muscle, which significantly simplified the modeling process. The necessary data for the muscle model were obtained from dynamic calculations carried out by M. DeMers for Gait2392.

After validation, the FEM model was enriched with a volumetric model of the femur, created based on data from computed microtomography. Each element of this model was assigned unique mechanical properties using the Zysset-Curnier model, combining the parameters of the bone's constitutive model with the structure tensor. Using the Abaqus environment, simulations of limb movement and loading were conducted, allowing for detailed information on the state of stress and strain of the femur in the normal gait cycle. The results allowed us to understand how the direction and amplitude of the pulling muscle forces and the load of body weight influence the state of stress inside the bone. A correlation was observed between the orientation of the trabecular structure and the directions of the main stresses. The conclusions drawn from the analysis are consistent with other literary works, but their precision and detail constitute a unique contribution to the topic of bone biomechanics research.

Keywords:

FEM, constitutive model, bone microstructure, gait cycle, human femur