INTRODUCTION

The biomechanical modeling have mostly been used to understand mechanical principles of the human body. Musculoskeletal models are used to predict muscle and joint reaction forces in order to analyze complex biomechanical problems, such as the functional outcome of surgery. Futhermore, musculoskeletal models have been applied to model the effects of a stroke, spinal cord injuries and sport injuries. The object of the study is the hip joint. Many biomechanical studies on hip joints and their replacements require detailed knowledge of the loads acting in this joint. The complexity of current patient-specific models is a reason of their rare use in the clinical practice. Therefore, multiple assumptions about model's geometry, mechanical properties and physiological parameters are adopted when using biomechanical models in clinical studies. Within the current study, we would like to specify how the assumptions used in model constructions influence their results. The principal aim of this thesis is to assess how a patient-specific hip joint modeling affects prediction of biomechanical parameters in comparison to generic models. The aim is to evaluate how a patient-specific model affects prediction of biological outcome of surgery. Furthermore, musculoskeletal models have been applied to simulate the effects of some disease and muscle group to hip muscle force and to hip joint reaction force prediction.

SPECIFIC AIMS

1. Verify hypothesis that the magnification of radiographs depends on the workplace where it is taken.
2. Test the hypothesis that obesity type affects hip radiographic magnification and quantify the relationship between patient body mass index and radiographic magnification.
3. Quantify the effect of isotropic and anisotropic scaling on the hip joint reaction force assessment.
4. Validate a generic musculoskeletal model of the lower limb by comparison of predicted hip joint reaction force to experimental data.
5. Determine the effect of maximum isometric force change in individual muscle and muscle group to hip muscle force and to hip joint reaction force prediction.
6. Determine the effect of patient-specific hip joint geometry on hip contact stress distribution.

DEPENDENCY OF RADIOGRAPHIC MAGNIFICATION ON THE WORKPLACE

Within this study, radiographic magnification was estimated on 337 radiographs of patients after total hip surgery from five orthopaedic departments in the Czech Republic. Magnification (M) was determined for each patient as a ratio between diameter of implanted femoral head measured on radiograph and its true size. One-way ANOVA revealed significant differences in magnification between workplaces (F(4,332)=19.2; p=0.001). These results suggest that radiographic magnification depends on the workplace where it is taken or more precisely on radiographic devices, it indicates potential limits in generalizability of results of studies dealing with preoperative planning accuracy to other institutions.

RELATIONSHIP BETWEEN BODY HABITUS AND RADIOGRAPHIC MAG.

Digital radiographs of 303 patients who underwent THA were taken from clinical archives. The size of implanted femoral head was taken as an internal calibration marker to estimate radiographic magnification. Patients were stratified into obesity categories by body mass index (BMI). Patients' mass, BMI, and body surface area (BSA) were studied as predictors of hip magnification. There is a significant effect of obesity type on hip radiographic magnification (one-way ANOVA, p<0.001). The radiographic magnification correlates with patients' mass (r=0.443, p<0.001), BMI (r=0.450, p<0.001) and BSA (r=0.442, p<0.001). For every 1 kg/m² increase in the BMI and for every 0.27 m² in the BSA there is a 1 percent increase in the hip radiographic magnification. The increase in hip radiographic magnification with mass, BMI, and BSA is higher in females than in males. We recommend 0.7 percent for males and 1.2 percent for females is added to the radiographic magnification estimated for normal-weight patients.

EFFECT OF ISOTROPIC AND ANISOTROPIC SCALING

356 hips from 250 radiograms of adult human pelvis were analyzed. A musculoskeletal model was constructed from sequential images of the Visible Human Male. The common body position and calculated forces

DISTRIBUTION OF HIP CONTACT STRESS

Although the peak contact stress is greatly influenced by individual gender, the difference in the mean stress and the contact area are considerably lower. Figures above presents a distribution of contact stress on weight bearing area and differences between the radiographic (spherical) model and CT (patient-specific) model. For given analysis, the stress was evaluated at the center of area of each element in the radiographic model. Most of the elements have error in contact stress estimation lower than 0.5 MPa (Figure left). Similar results have been observed when analyzing hip joint contact stress distribution during one step of walking.

EFFECT OF HIP JOINT GEOMETRY ON HIP CONTACT STRESS

The aim of this part is to determine how the patient-specific geometry of weight-bearing area affects the estimation of contact stress distribution. Two patient specific models based on CT and MRI images were created.

SELECTED AUTHOR'S PUBLICATIONS


The basic method of model verification is comparison to the experimental data. In this study, the hip joint reaction force was calculated by musculoskeletal model using inverse dynamic optimization. Measured data (MD) from telemetric prostheses of Bergmann et al., 2001 were used. The influence of type of scaling to the hip joint reaction force was observed. An OpenSim musculoskeletal model was scaling nonuniformly (NS), uniformly by body height (BH) and uniformly by body height except of pelvis, that was scaled nonuniformly (BHP).

One-sample t-test revealed significant magnification differences at the pelvis (T(336)=5.5; p<0.001). Drop actuator (glut med 1) was doubled to study the effect of localized strengthening. B) all muscle actuators corresponding to principal muscle abductors gluteus medius and minimus (6 actuators) were strengthened by doubling their respective maximum isometric force.

5 EFFECT OF CHANGE MAXIMUM ISOMETRIC FORCE IN THE MUSCLE

Within this study, a generic muscle model with 23 degree of freedom and 92 muscle-tendon actuators was adopted. Each muscle was configured to extend maximum isometric force. The activation in hip abductors was observed. A) the maximum isometric force in single muscle-tendon actuator (glut med 1) was doubled to study the effect of localized strengthening. B) all muscle actuators corresponding to principal muscle abductors gluteus medius and minimus (6 actuators) were strengthened by doubling their respective maximum isometric force.

6 EFFECT OF HIP JOINT GEOMETRY ON HIP CONTACT STRESS

The aim of this part is to determine how the patient-specific geometry of weight-bearing area affects the estimation of contact stress distribution. Two patient specific models based on CT and MRI images were created.

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