THE STRESS LEVEL ANALYSIS FOR DYNAMIC CASES AT HUMAN HIP JOINT

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INTRODUCTION

The estimation of hip joint stress level is very useful for both preoperative planning and postoprerative rehabilitation. Since 1980's, Bergmann and his research group have been pursuing the instrumented hip implants with telemetric data transmission. Their collected gait data were recorded in HIP98, and updated in 2001[1]. So far it is unique gait database of the human hip contact force simultaneously measured in vivo. It is well recognized, however, that intrinsic pathomechanical changes in articulator cartilage depends upon local stress levels rather than upon global joint loading, and the abnormal mechanical stress upon hip joint cartilage is one of the main causes of osteoarthritis. In this paper, based on the Hertzian elasticity contact theory[2] and the hip dynamic measured data in vivo for the human various daily activities[1], such as walking slowly, walking normal, walking fast, going up stairs, going down stairs, standing up, sitting down and knee bending, a realistic stress level analysis for dynamic cases at the human hip joint are presented.

METHODS

1 Coordinate Systems

The three coordinate systems are established for the purpose of describing relationships between the hip motion and resultant load. They are, respectively, X, Y, Z system, X_C, Y_C, Z_C system and a spherical coordinate system ρ, θ, φ, as shown in Figure 1.

2 Stress Distributions on the Hip

The Hertzian theory for the elastic contact of two bodies with nonconforming geometrical shapes, which is suitable to the specific case of a sphere contacting inside a sphere, is employed to calculate the stress distributions on the hip[2]. The formulas are given in the following:

$$\sigma_t(\theta,\varphi)=\frac{3F(t)}{2\pi r^2(t)}\left[1-\frac{d_t^2(\theta,\varphi)}{r^2(t)}\right]^{1/2} \quad (1)$$

where

$$r(t)=\left[\frac{3\pi}{8}F(t)\left(\frac{1-\nu_H^2}{\pi E_H}-\frac{1-\nu_C^2}{\pi E_C}\right)\left(\frac{1}{D_H}-\frac{1}{D_C}\right)^{-1}\right]^{1/3} \quad (2)$$

$$d_t(\theta,\varphi)=\frac{D_C}{2}\sin\left\{\cos^{-1}\left[\sin\theta\sin\theta_P(t)\cos(\varphi-\varphi_P(t))+\cos\theta\cos\theta_P(t)\right]\right\} \quad (3)$$

3 Gait Data in vivo for Routine Activities

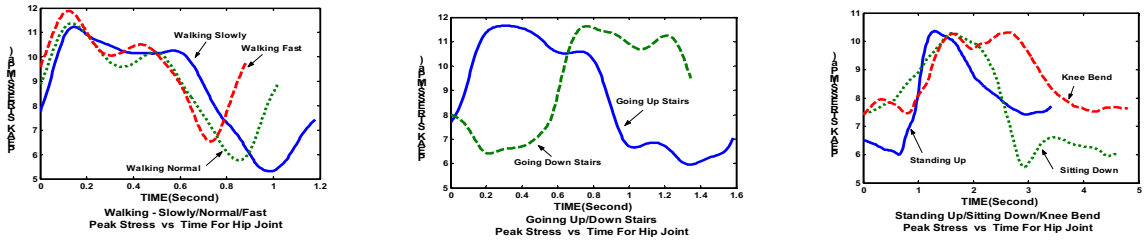

Figure 1 The peak stress comparisons at the hip joint for the human eight routine activities; (a) for walking cases: slowly, normal, and fast; (b) for going up stairs and going down stairs cases; (c) for standing up, sitting down, and knee bend cases.

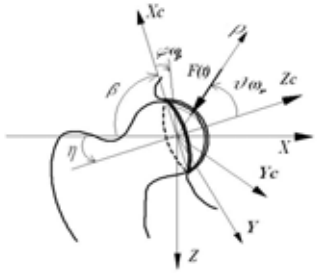

Figure 1: Coordinate System for the peak stress analysis

In 2000 version of HIP 98[1], the gait data in vivo for nine different human routine activities were collected, in which it is assumed to cause high hip joint loads and occur frequently in daily living. In this study, the gait data is taken from the patient H. Sonke[2]. The parameter values for peak stress evaluation are given as following: p=860N, $\eta=4^0$, $\beta=56.9^0$, D_c=28.2mm, D_h=28mm, E_c=900MPa, $\nu_c=0.4$, E_h=206GPa, $\nu_h=0.3$.

RESULTS AND DISCUSSION

In Figure 1, the comparisons for the peak stress curve in the human eight routine activities are given. The three types of walking cases, the two types of going up/down stairs cases and three types of standing up/sitting down/knee bend cases are, respectively, given in Figure 1(a), 1(b), 1(c). The results show that the higher peak stress level at the human hip joint in the walking fast case is existed. This is probably due to the fact with the higher contact force and with the larger inertia in walking fast case. This may reveals that the hip injury would be more probable when the human walks at the fast speed.

REFERENCES

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