

Validation Of Musculoskeletal Gait Simulation For Use In Investigation Of Total Hip Replacement

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Introduction

Current methods of analysing total hip replacements rarely include the effect of the muscle forces acting on the hip in a detailed manner. The musculoskeletal models presented here will be used to compute muscle forces for application to a finite element model of a femur with an implanted prosthesis allowing more detailed and accurate analysis of implants than is possible with simplified load cases commonly adopted.

Methods

This study uses a musculoskeletal model of the lower extremity created at the AnyBody Research group, Aalborg University with the modelling programme AnyBody. The programme uses inverse dynamics to calculate the muscle forces from pre-recorded marker positions. The muscles are recruited using an assumed optimisation criterion minimising the sum of the squared muscle activities. The calculation of the instantaneous muscle strength is based on a Hill type model.

Using the lower limb model two simulations were created using separate gait analysis data sets. One model was created using data from a "normal" man [Vaughan, 1992] and the other data set was obtained from S. Asfour at the University of Miami. Hip contact forces from the AnyBody models have been compared to published experimental data from Bergmann et al [Bergmann, 2001] and Brand et al [Brand, 1994] where the forces at the hip were measured directly.



Figure 1: Musculoskeletal lower limb model in AnyBody. Model contains 72 muscle units and seven segments which are jointed by a spherical joint at the hip, a hinge joint at the knee and a universal joint at the ankle.

Results

The results shown in figures 2, 3 and 4 are, in general a positive indication that the AnyBody model using data from Vaughan et al and from Miami have a similar pattern and magnitude of force compared with experimental data from the literature [Brand, 1994; Bergmann, 2001]. Joint torque and hip contact forces are normalised with the subject's body weight. The joint torque can be considered a direct comparison of the subjects involved since it is calculated directly from the input data and does not require assumptions to be made about the muscle recruitment or muscle strength.

- Generally the forces calculated in the AnyBody models are higher than the forces from the literature. However the abduction/adduction joint torque (figure 5) at the hip for the Miami patient is also larger than the torque calculated for the patients in Bergmann et al's study.
- There is larger extension torque (figure 7) for both Miami and Vaughan patients than for the Bergmann patients at toe off and there are larger compression forces at toe off for both models.
- There is a difference in the torque pattern in flexion/extension at the 20% of the gait cycle and a large lateral contact force in the Miami model at this point in the gait cycle.
- The joint torque and contact force across the hip during the swing phase, approximately 70% - 100% of gait cycle, are similar in all the patients.
- Calculated anterior forces are similar to the measured literature data.

The patients from Bergmann et al's study have a greater range of abduction/adduction torque during the recorded gait cycle than the Miami and Vaughan patients which would affect the variation between the patients' forces at the hip. There is also variation within a single patient, the variability in the forces calculated at both the right and left hips of the Miami model is also reflected in the differences between the two legs' abduction/adduction torques

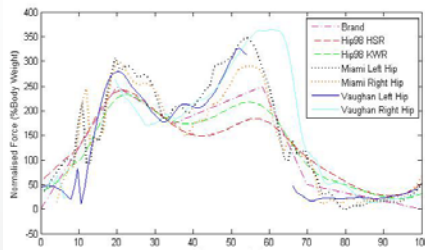


Figure 2: Hip Joint Force On The Femoral Head In Inferior Direction

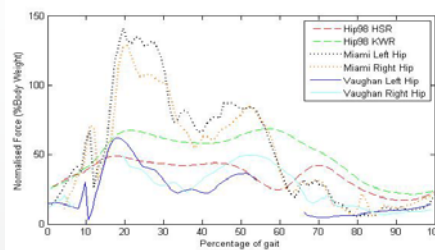


Figure 3: Hip Joint Force On The Femoral Head In Lateral Direction

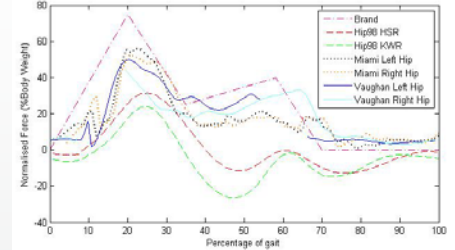


Figure 4: Hip Joint Force On The Femoral Head In Anterior Direction

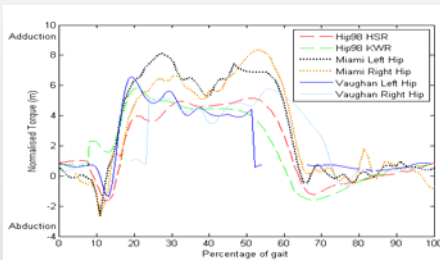


Figure 5: Abduction/Adduction Torque At The Hip

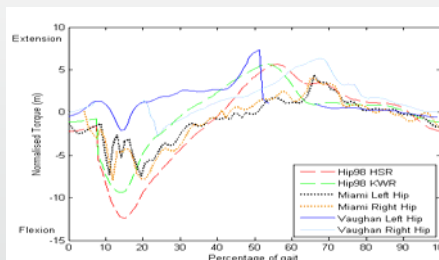


Figure 7: Flexion/Extension Torque At The Hip

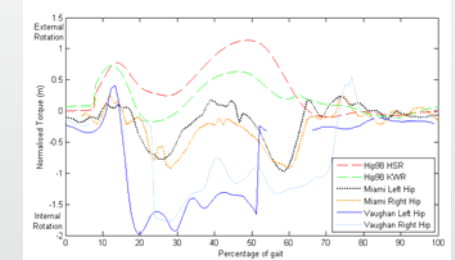


Figure 6: Internal/External Rotational Torque At The Hip

Conclusion

The hip reaction forces calculated in AnyBody using the gait analysis data from Vaughan and Miami have some differences to the measured data from the literature. However, the calculated values, except the large lateral force at heel strike, are within the variability that this study has shown to be present between different patients and between gait cycles for a single patient and is therefore possibly due to individual variation between patients.

References

- Bergmann, *et al*, J Biomech, **34**:859-871, 2001.
Brand, *et al*, J Arthroplasty **9**(1):45-51, 1994.
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