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HIP CONTACT FORCES IN HEALTHY AND HIP OSTEROARTHRITIS POPULATION

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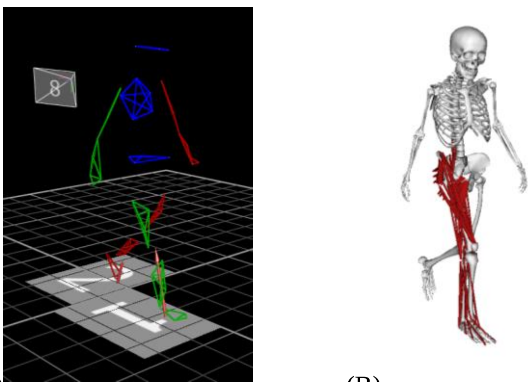
INTRODUCTION

Hip osteoarthritis (OA) is a progressive and debilitating disease for which there is no cure and poses an economic burden on the healthcare system [1]. Mechanical wear of the hip joint may be an important factor in the development of hip OA [2, 3]; however, hip joint disease is relatively under-studied and mechanical factors for the progression of hip OA are still poorly understood. Musculoskeletal models can estimate muscle forces and joint contact forces and it has been shown that reasonable hip contact forces (HCFs) can be obtained compared to in vivo measurements [4, 5]. The purpose of this research is to investigate the articular loading at the acetabulo-femoral joint during daily living activities in healthy and hip osteoarthritic population.

METHODS

A musculoskeletal model was developed in OpenSim [6] to compare the hip contact forces in healthy and hip OA subjects. The model is based on a publicly available anatomical dataset describing the attachments of 163 actuators (representative of 38 muscles) and the parameters for modeling the lower limb joints [7]. The original model [8] has been extended with an upper body [9] and inertial parameters and joint positions updated according to [10]. The full body model can be seen in Figure 1 (B).



(A) (B)

Figure 1: (A) Experimental gait data collected on hip OA subjects and controls (B) OpenSim model adopted for the simulations.

We recruited and tested 20 individuals (> 45 years) with unilateral radiographic hip OA that has Kellgren-Lawrence (KL) score of 2 or 3 and 20 age-matched and gender matched healthy controls to enable direct comparisons between hip OA affected and unaffected individuals. In this abstract, only a healthy male subject and a hip OA female subject will be presented. The healthy male subject was 181cm with mass of 88kg. The hip OA female was 171cm with mass of 80kg.

Participants were fitted with a full-body retro-reflective marker set. As per the methods used in the Griffith University motion capture laboratory [7, 8] the system and data include: (i) 10MX-camera Vicon system, sampling at 200 Hz, and (ii) two AMTI force platforms, each sampling at 1,000Hz, from which ground reaction forces were collected.

Participants performed a series of static, functional, and dynamic trials in the motion capture laboratory. Static and functional trials were used to scale our OpenSim generic model to the subject's anthropomorphic dimensions [9]. Functional trials include squats and leg swing motions that were used to estimate joint centers and functional joint axes for the knee and hip joint [11]. Dynamic tasks include walking and sit-to-stand task. There were 10 trials per tasks. These tasks represent some of the most common daily activities. Due to having 2 force plates, walking trials were cropped to start at left leg toe-off and ends at right heel strike.

Markers and ground reaction forces (GRF) were filtered and converted into formats compatible with Opensim. From OpenSim, inverse kinematics was used to calculate joint angles for each dynamic task while inverse dynamics was used to determine the net forces and torques at each joint. To estimate muscle forces, a static optimization technique was implemented. This technique involves minimizing a physiological function representing the muscle forces to estimate muscle forces. Using this, we can estimate HCFs. HCFs were normalized to the subject's body weight (BW).

RESULTS AND DISCUSSION

HCFs for the control and hip OA subject can be seen in Figure 2 and 3, respectively. Due to the limitation of having only 2 force plates, the start of the simulation is at left toe off (~12% gait cycle) and ends at right heel contact (100% gait cycle). The mean peak HCF for the control subject was 456 %BW while the peak for the hip OA subject was 380 %BW, which is about 17% lower compared to the control subject. This peak occurred at around 55% of the gait cycle for both control and hip OA subject. However, the trough that occurs at a little over 30% of the gait cycle is much larger (38% higher) for the hip OA subject versus the control subject. Correlation coefficient for the contact forces for the hip OA subject and control subject was 0.791.

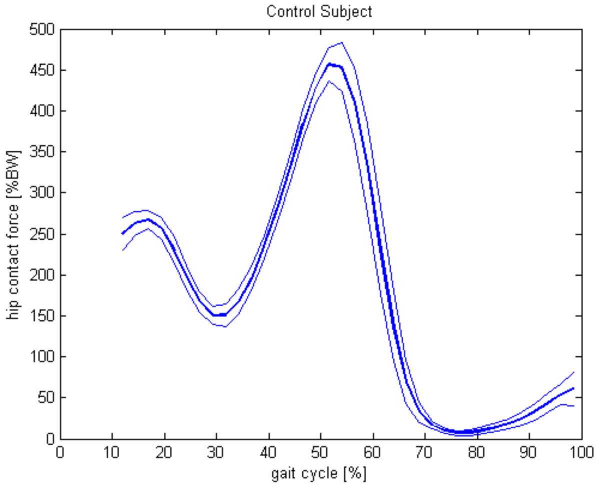


Figure 2: Right hip joint contact force for the control subject during walking. The thick blue line is the average from the 10 walking trials while the thin blue line represents 1 standard deviation. Peak HCF occurs at around 55% of the gait cycle.

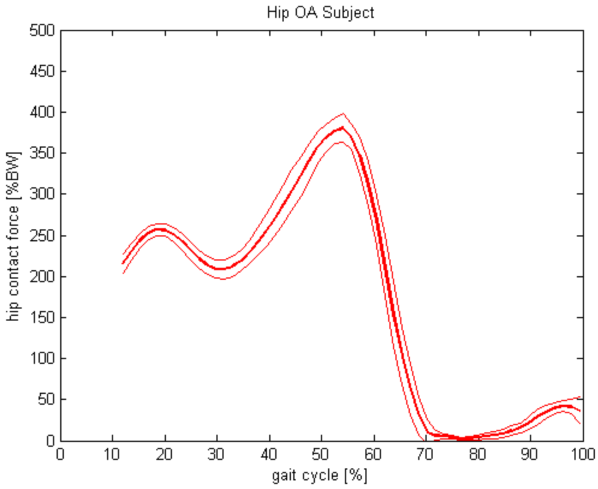


Figure 3: Right hip Joint Contact Force for the hip OA subject during walking. The thick red line is the average from the 10 walking trials while the thin red line represents 1 standard deviation. Peak HCF occurs at around 55% of the gait cycle.

There were several challenges in our study. We are comparing a male and a female subject with different weight and height due to the availability of data at the time of this writing. However, we have normalized the hip contact forces as a percentage of the subject's body weight. We only have 2 available force plates which made it impossible to look at the whole gait cycle. From left toe-off to right heel strike, however, is about 88% of the gait cycle. We only included actuators in the right leg of the model. This was the side of interest to calculate HCJs and simplified our musculoskeletal model for faster analysis. We have included muscle parameters (e.g. contraction dynamics, force-length relationship) which were not implemented in the London Lower Limb model.

CONCLUSIONS

Despite limitations connected with the musculoskeletal model, the presented methodology proved to be promising in catching relative differences of the joint contact forces in the control and hip OA patient. This is preliminary data for a much larger 12-month prospective study to investigate mechanical loading across the acetabulofemoral joint during daily living activities in healthy and hip osteoarthritic population.

Future development of this investigation will be the integration of the existing musculoskeletal model with an EMG-informed neural toolbox [12] to calculate muscle forces based on the EMG data that we collected during the gait lab sessions for 16 muscles.

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