**Dependency Of Hip Joint Reaction Forces On Hip Joint Centre Location During Walking**

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## Summary

The hip joint center (HJC) is a crucial point in musculoskeletal (MSK) models. Its location is usually estimated by the position of pelvic anatomical landmarks. Due to several uncertainties, the real HJC location remains unknown if clinical images are not available. This study examined the impact of HJC location on hip joint reaction forces (HJRF). An MSK model was developed in OpenSim to simulate the gait of a patient with an instrumented hip joint prosthesis. The baseline model was then modified perturbing the HJC locations 51 times. Results showed the HJRF dependency on medial/lateral displacement from the baseline position. The analyses will be extended to the entire dataset (10 patients).

## Introduction

Accurate estimation of the hip joint center (HJC) is crucial in human motion analysis, as it significantly influences lower limb kinematics and kinetics [1,2]. In human motion simulations, the scaling of a generic musculoskeletal (MSK) model to the participant anthropometrics can be a source of inaccuracy for the HJC location, affecting the estimation of internal loads. Bartels et al. [3] demonstrated that CT-based models enhance joint moment accuracy compared to scaled models, while Lenaerts et al. [4] showed that incorporating CT-derived HJC location significantly impacts hip joint reaction force (HJRF). However, to the authors' knowledge, no previous study has evaluated the HJRF derived from HJC sensitivity against the gold standard of experimental measurements from instrumented prosthesis in the same patient. Accordingly, the aims of this study are, after the validation of a baseline simulation, to evaluate the effect of varying the HJC location on the resultant HJRF. One of the evaluated positions will be the HJC estimated from CT scans.

## Methods

For this study we considered the Hip III OrthoLoad dataset [5], consisting of 10 patients with an instrumented hip prosthesis performing a single gait trial each, and we preliminarily present results for subject H2R (male, 62 y.o., height: 172 cm, body weight (BW): 767 N, 12 month post-operatively). First, we scaled the generic Rajagopal full-body MSK model to the anthropometrics of H2R using a single frame of the gait trial and weaken the hip-spanning muscles to simulate a typical post-THA condition. We then simulated the available gait trial with this model (*baseline simulation*). Secondly, we modified the HJC of the baseline model applying a total of 51 perturbations within a sphere of 0.03 m radius [1] using the OpenSim API (Figure 1a). These modifications altered the skeletal anatomy without affecting the musculotendon paths. For each perturbed model, the HJRFs were predicted with a standard inverse approach in OpenSim using static optimization to compute the muscle forces. Finally, we also created a model with HJC location consistent with the CT landmarks included in the Hip III dataset. The predicted and measured HJRF were compared using root mean square error (RMSE), coefficient of determination ($R^2$), and peak errors.

## Results and Discussion

The baseline model showed an RMSE of 0.59 BW, a maximum peak error of 0.85 BW at push-off (PO), and an $R^2$ of 0.87 with respect to the instrumented prosthesis data. In the sensitivity study, a 3 cm lateral shift of the HJC led to an overestimation of HJRF, with peaks reaching 2.72 times the measured value at heel strike (HS). Conversely, a 3 cm medial shift resulted in an underestimation of both HS and PO peaks equal to 0.86 times the measured value (Figure 1b). Finally, personalizing the HJC using CT landmarks, which placed it 3.56 cm from the scaled location, also led to an overestimation of HJRF (RMSE: 1.12 BW).

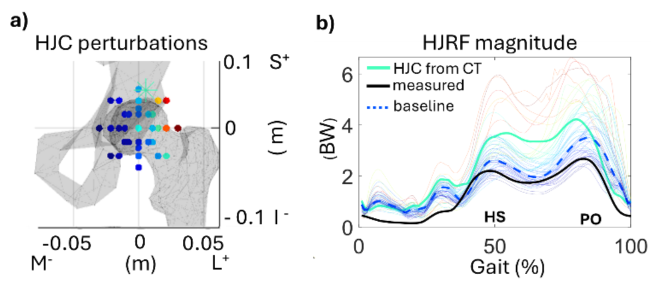


**Figure 1**: a) HJC perturbations and CT derived HJC (light blue asterisk); b) Predicted and measured HJRF (magnitude). Curve color in b) corresponds to the HJC symbol color in a).

## Conclusions

Our preliminary results suggest that consistency of the MSK model anatomy yields a more accurate prediction than partial personalization of the HJC, even if based on medical images. Based on the sensitivity study, a lateral shift of the HJC location results in an overestimation of the HJRF during gait. The study is currently being extended to the other Hip III patients.

## References

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