Hip Joint Contact Force In Femoroacetabular Impingement Population During Walking: An Exploratory Study

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Introduction: Femoroacetabular Impingement (FAI) of type cam is an anatomical deformity of the hip, associated with groin pain and reduced hip range of motion, and it is considered a leading factor to hip osteoarthritis [1]. Severe labral tears can be noticed in surgical FAI patients at the site of the impingement [2]. Motion analysis revealed that, in presence of FAI, range of motion is reduced at both the sagittal and frontal planes during everyday activities such as walking, squatting and stairs climbing [3, 4]. Electromyography (EMG) investigation on the FAI population performed during isometric contractions [5], revealed an impaired ability to voluntarily activate Tensor Fasciae Latae and Rectus Femoris. However, EMG analysis alone is not sufficient to assess muscular force production and joint contact force, which would greatly increase the understanding of FAI biomechanical alterations and development.

Finite element analysis studies tried to clarify FAI pathomechanics using external loads calculated from inverse dynamics [6]. However, these methods exclude the effect of muscle forces that are speculated to contribute more than 70% to the total hip contact forces (HCF). Therefore, hip muscle forces are necessary to obtain more realistic HCF.

With the ultimate goal of understanding the pathomechanisms of FAI, the purpose of this study was to investigate the differences in HCF between FAI and control participants during a dynamic task such as level walking, and to examine the effect of the FAI deformity on the hip contact forces. It was hypothesized that the FAI group who have a reduced HCF as consequence of adaptive mechanisms to pain, similar to what has been revealed in patients with labral pathology [7].

Methods: Thirteen healthy male participants (age: 33±7 years, BMI: 25.3±2.9 Kg/m2) and thirteen male symptomatic FAI patients (age: 35±7 years, BMI: 25.7±2.5 Kg/m2) were included for this study. The inclusion criteria for the FAI group were: alpha angle measured from computer tomography higher than 50.5º in the axial view, higher than 60º in the radial view and a positive impingement test [8]. Participants affected by musculoskeletal problems in the lower limbs other than FAI were excluded from the analysis. The control group (CON) were recruited from the general population, and matched for gender, age and BMI to the FAI group.

Participants were instrumented with reflective markers according to a modified Plug-in-Gait markerset. The motion capture system included ten infrared Vicon MX-13 cameras (sampling at 200Hz) and two Bertec force plates (1000Hz). Every participant executed five repetitions of level walking trials at a self-selected pace.

Motion capture data were processed in Matlab (2013b) and subsequently exported into OpenSim (3.1), where inverse kinematics, kinetics and static optimization analyses were performed. The anatomical model was adapted from the one proposed by Hamner et al [9]. Muscle forces were computed using a static optimization approach with a quadratic cost function. Tri-dimensional hip contact forces were
calculated and expressed in the pelvic reference system. The trials were analyzed during the single stance phase, and a series of one-tailed t-tests were performed on the peak values of the HCF (confidence level = 95%, independent variable = group), to verify the hypothesis.

**Results:** Average stride length and velocity were similar for FAI and CON, eliminating the potential influence of these factors on HCF. Kinematics and kinetics outcomes were not significantly different between the two groups, potentially due to the small sample size. However, slight reduction in frontal pelvic and hip ranges of motion was seen in the FAI group, as previously noticed in the literature. As for static optimization outcomes, the results of this analysis are comparable with the available data in the literature. In fact, the obtained resultant hip contact force ranged between 1.5 and 6 body weights (BW) (Figure 1), close to the results obtained by Bergmann et al [10] when measuring HCF with instrumented prostheses during walking.

The two groups showed similar HCF amplitudes in the three dimensions throughout the first 70% of the single stance phase, but differ towards the end where the resultant HCF peaks again before the contralateral foot-strike. The one-tailed t-test revealed a statistically significant reduction for the resultant peak HCF (-7.3%, p-value = .036) in the FAI group, mostly due to the antero/posterior component of the HCF, which registered a strong trend of HCF peak reduction (-14.1%, p-value =.055).

**Discussion:** Towards the end of the single stance phase the direction of the resultant HCF is anterior (Figure 2), since the femur is compressing against the acetabulum. The significant reduction in compression force registered in the FAI population could suggest a tendency of these participants to protect the joint against excessive anterior loads compressing against the site of the impingement. In fact, even if participants did not report pain during the execution of the walking task, this could be the result of a neuromuscular adaptation mechanism due to fear of pain, similarly to what was discussed for the labral tear population by Mendis [7]. This observation also supports the theory proposed by Casartelli [5] and Kennedy [3] who suggested for first the presence of a protective mechanism of the hip joint in presence of FAI signs.

**Significance:** The significance of this study is to provide an understanding of how FAI deformity alters hip joint contact forces, and whether motion analysis and HCF estimation could be used a diagnostic tool to predict the presence of deformations and labral damages.
Figure 1 Resultant hip contact force for CON (plain) and FAI (dashed) groups. The curve is from contralateral foot-off (C-FO) to foot-strike (C-FS).

Figure 2 Hip contact forces (antero/posterior and vertical components) for CON (plain) and FAI (dashed) groups. HFC are in BW right before the contralateral foot-strike (C-FS).

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