Altered Muscle Synergies in Cam FAI to Maintain Spinopelvic Stability during the Squat Task

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INTRODUCTION: Cam-type femoroacetabular impingement (FAI) is characterized by an asphericity or enlargement of the femoral head that slowly damages the surrounding articular cartilage and labrum and often leads to premature hip osteoarthritis [1]. Symptomatic FAI patients adapt their movements to reduce loading in their painful hip [2]; however, how this is reflected in patient muscles and whether patients rely on altered muscle synergies to carry out dynamic flexion-related tasks, where impingement risk is greater, is still unknown. The aim of this study was to delineate the core and lower-limb muscles synergies between the symptomatic affected hip (FAI-SYM) and contralateral, asymptomatic unaffected hip of cam FAI patients (FAI-ASYM) and compare them with healthy controls (CON) during the squat task.

METHODS: Fifteen symptomatic unilateral cam FAI patients awaiting surgery (n = 15, m:f = 8:7, age = 27 ± 8 years, BMI = 24 ± 5) and 15 healthy controls, matched by age, sex, and BMI (n = 15, m:f = 7:8, age = 25 ± 8 years, BMI = 24 ± 4), were recruited. All participants underwent 3T MR imaging to measure their anatomical parameters and quantify/confirm the status of their cam deformities or healthy control hips. Participants were then brought to the motion capture biomechanics laboratory to perform a functional assessment. Twelve surface electromyography (EMG) electrodes (Trigno, Delsys; USA) were positioned to each participant's left and right lower-limb and core muscles, including: gluteus maximus (GM), biceps femoris (BF), tensor fasciae latae (TFL), rectus femoris (RF), erector spinae (ES), and rectus abdominus (RA). Each participant performed squats (Figure 1A) and maximum voluntary isometric contractions (hip extension, knee flexion, hip flexion & abduction (combined), hip flexion, back extension, abdominal crunch exercise), with the peak EMG signal captured to normalize EMG data for each muscle (GM, BF, TFL, RF, ES, RA, respectively). EMG data was processed using a custom script in MATLAB (MathWorks, USA). The EMG signals were aligned by movement phase (0% = start, 50% = maximal depth, 100% = end), filtered using a dual-pass, zero lag fourth order Butterworth filter (20-500 Hz bandpass), and smoothed using a 6 Hz dual-pass, zero lag fourth order, lowpass Butterworth filter. The spatial (synergy weightings) and temporal characteristics (excitation primitives) were extracted for four synergies using weighted non-negative matrix factorization [3]. The variance accounted for (VAF) was calculated for each individual muscle and globally for all (Figure 1B) to evaluate the synergies' ability to reconstruct the original signals. VAFs between each FAI patient's symptomatic and asymptomatic hip were compared using the Wilcoxon signed-rank test, while the Mann-Whitney U test was used to compare those of the FAI group to the control group ($P < 0.05$).

RESULTS SECTION: Reconstruction of the rectus femoris ($P = 0.02$) and erector spinae muscle activity ($P = 0.03$) was near perfect in all three comparison groups, while those of the gluteus maximus were only reconstructed well in the FAI group ($P = 0.02$). The rectus abdominus saw much poorer reconstruction in the FAI group compared to the control group ($P = 0.01$). Lastly, the control group saw slightly better reconstruction globally compared to the FAI group.

DISCUSSION: The key finding was that FAI patients showed altered synergistic contributions of their gluteus maximus and rectus abdominus to complete the squat task. Lower VAF in the patients' rectus abdominus but greater VAF in their gluteus maximus could indicate compensatory action in the gluteal muscles to offset suboptimal core recruitment and maintain adequate spinopelvic stability while squatting. The lower global VAF and less organized synergies suggest impaired neuromuscular coordination and inefficient recruitment strategies in FAI patients.

SIGNIFICANCE/CLINICAL RELEVANCE: A clearer understanding of compensatory mechanisms can help guide prehabilitation/rehabilitation protocols by revealing harmful recruitment patterns prior to hip exacerbation, in turn addressing early symptoms, alleviating pain, and improving hip-pelvic stability in efforts to personalize non-surgical management.

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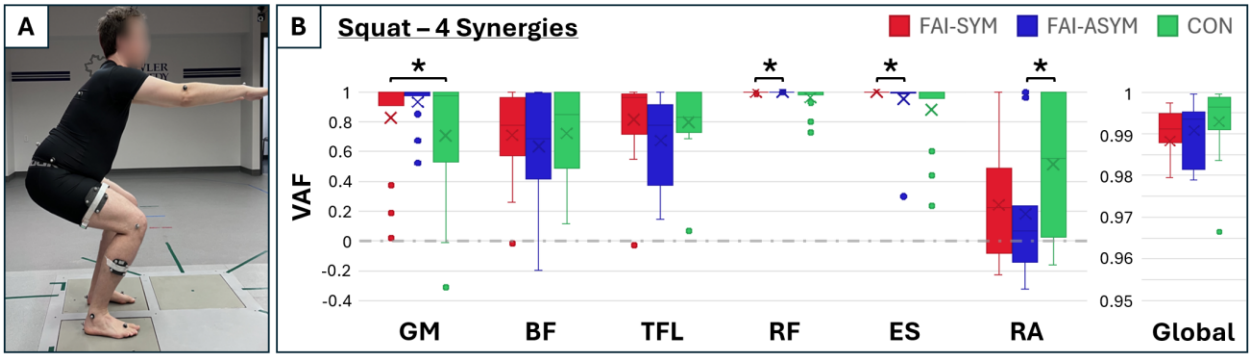

Figure 1. (A) Maximal squat depth during the functional assessment. **(B)** Variance accounted for (VAF) globally and of each muscle for the FAI-symptomatic (FAI-SYM), FAI-asymptomatic (FAI-ASYM), and control group (CON).