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Hip and Pelvic Kinematics in FAI Patients Differs Between Constrained and Unconstrained Squatting

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Summary:
Hip and pelvic kinematics in FAI patients differs between constrained and unconstrained squatting. Squatting methods need to be standardized for accurate comparisons of results in the literature.

Abstract:
Introduction:
Maximal depth squatting is an exercise that approaches the extremes of hip joint motion and has been used to evaluate hip and pelvic kinematics. In patients with femoroacetabular impingement (FAI), maximal depth squatting has been used to evaluate whether patients have altered kinematics to compensate for their injury. Many patients with FAI have difficulty with combined high flexion and internal rotation angles, and have been theorized to abduct their hip during squatting to avoid the bony conflict. Therefore, constraining the squat to strictly the sagittal plane may emphasize the altered kinematics in these patients. The goal of this study was to investigate hip and pelvic kinematics during constrained and unconstrained squatting, and identify functional adaptations in FAI patients. It was hypothesized that unconstrained squatting would allow FAI patients to squat deeper and with greater hip abduction than during constrained squatting.

Methods:
This study was approved by the governing Institutional Review Board and all participants gave their written informed consent prior to participating. Fourteen patients diagnosed with FAI were recruited to participate in this study (age: 28.0 ± 5.8 years, height: 179.0 ± 9.2 cm, weight: 80.4 ± 12.2 kg, 12 M, 2 F). Participants performed two squatting motions, starting from standing with their feet shoulder width apart and both arms extended, squatting down to a maximal depth, and returning to a standing position at a self-selected pace while maintaining heel contact throughout the movement. For the first type of squat, no additional directions were given (unconstrained squat). For the constrained squat, the participants were given the additional constraint that their feet had to remain parallel to each other and their knees had to track directly over their toes which limited this motion to the sagittal plane only. Kinematics was determined using a 10-camera motion capture system (Eagle, Motion Analysis Corp, Santa Clara, CA) and The MotionMonitor software (Innsport, Chicago, IL, USA). The maximum squat depth was expressed as a percentage of the height of the marker placed on the sacrum during neutral stance. Hip flexion, abduction, and internal rotation angles were calculated relative to the pelvis, and the orientation of the pelvis relative to the laboratory floor was also calculated. All angular measurements were made at a standardized depth of 75% of the neutral stance height to account for differences in maximum squat depth. Matched pairs t-tests were used to compare squat depth and angular measurements between constrained and unconstrained squatting.

Results:
Kinematic differences were found between constrained and unconstrained squatting, specifically in squat depth, hip abduction, hip internal rotation and pelvic rotation in the frontal plane. The maximum squat depth was significantly

different between unconstrained and constrained squatting (46.0 ± 15.1% and 60.2 ± 12.8% of stance height, respectively; $p < 0.001$). Additionally, unconstrained squatting allowed greater hip abduction than constrained squatting (12.9 ± 23.9º and 8.0 ± 24.0º, respectively; $p < 0.010$), and less internal rotation (9.2 ± 9.6º and 12.0 ± 8.5º, respectively; $p < 0.050$) at 75% of stance height. While not significant, increased pelvic rotation in the frontal plane was found during constrained squatting compared to unconstrained squatting (12.3 ± 10.3º and 10.9 ± 8.9º, respectively; $p = 0.071$).

Discussion:
Our hypothesis that FAI patients would squat deeper during unconstrained squatting than constrained squatting was confirmed. Constrained squatting required greater internal rotation and less hip abduction, which is expected when the squatting motion is limited to the sagittal plane. Increased pelvic rotation was found in the frontal plane during constrained squatting, which could be due to relying on a dominant leg to maintain form and balance. These findings suggest that the squatting method can greatly influence kinematic results, and should be taken into account in future studies of squatting kinematics.

Significance:
Squatting methods need to be standardized across the literature. Hip and pelvic kinematics differs between constrained and unconstrained squatting in FAI patients, and the details of the squatting method should be described in the literature to allow accurate comparisons of the results.