DEEP HIP MUSCLE ACTIVATION DURING A SQUAT EXERCISE

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INTRODUCTION

Hip joint function during a squat has recently received increased clinical attention due to the growing awareness of femoroacetabular impingement (FAI) [1]. During a squat, patients with FAI demonstrate restricted pelvic motion and hip flexion, internal rotation and abduction due to inappropriate contact of the femur and acetabulum [2]. Muscular dysfunction of the pectineus, iliopsoas, gluteus medius and piriformis muscles in concert or isolation may enhance this irregular mechanical relationship but diminutive information is available regarding their function.

The purpose of this study was to describe the activation of the pectineus, iliopsoas, gluteus medius and piriformis muscles during a squat.

METHODS

Ten healthy individuals (1.72 ± 0.04 m; 674.17 ± 43.3 N; 28.70 ± 2.00 y) participated in this study. All participants provided written consent prior to participation, in accordance with the Vail Valley Medical Center's Institutional Review Board.

The participants performed a squat similar to a rehabilitation exercise (~2/3 of maximum squat). The squat exercise was performed at a pace of 0.5 Hz. Indwelling electrodes were used to record (1200 Hz) muscle activation from the pectineus, iliopsoas, gluteus medius and piriformis muscles. The electrodes were ultrasound guided to assure correct placement into the muscle and for patient safety. Electrode placement was confirmed via inspection of the digital ultrasound pictures by a radiologist that was blinded to the study.

All EMG data (Bagnoli-8, DelSys, Boston, MA, USA) were processed with a 50 ms, root-mean-squared (RMS) moving window (1 ms increments) with custom software (MATLAB, Natick, MA, USA). The EMG data were scaled to maximum EMG reference values measured during the MVC trials and represented 100% MVC.

Fifty-three retro-reflective, spherical markers (diameter =1.0 cm) were attached to select anatomical landmarks. A ten-camera motion analysis system (Motion Analysis, Cortex 1.1.4, Santa Rosa, CA, USA) was used to capture three-dimensional hip motions at a frequency of 120 Hz. The marker trajectories were low pass filtered at 10 Hz with a fourth order Butterworth filter.

Three-dimensional hip and pelvis kinematics were calculated with a commercial software package (Motion Monitor, Version 7.0, Innovative Sports Training, Chicago, IL, USA). Joint angles were determined using a YXZ sequence as proposed by Grood and Suntay [3] such that sagittal joint motion was represented as rotations about the y-axis, frontal plane motion represented by rotations about the x-axis and transverse plane motion as rotations about the z-axis.

RESULTS

When rising from a squatted position, the hip joint progressively extended from 54.8 ± 3.6º of hip flexion to 4.4 ± 2.8º of hip flexion; abducted from 0.5 ± 2.5º of hip adduction to 2.3 ± 1.5º of hip abduction; and externally rotated from 0.8 ± 1.7º of hip internal rotation to 4.1 ± 1.4º of hip external rotation. The pelvis rotated posterior from 19.2 ± 3.0º of anterior pelvic tilt to 5.9 ± 1.9º of anterior pelvic tilt. The lowering phase demonstrated equal and opposite hip and pelvic motions.

The ensemble EMG time series data are located in Figure 1. The EMG amplitude values ranged between 2.3 ± 7.1 %MVC and 33.4 ± 10.1 %MVC.

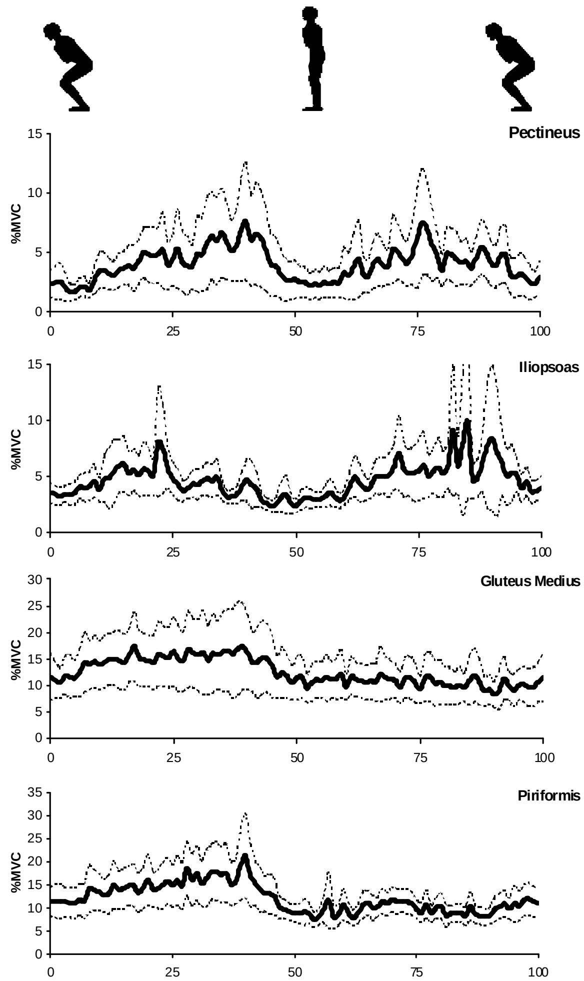

Figure 1. Mean (±SE) ensemble EMG activation patterns for the pectineus, iliopsoas, gluteus medius and piriformis muscles during a squat when rising (0-49%) and lowering (50-100%).

DISCUSSION

It is believed that the deep muscles of the hip may provide fine control of hip joint stability, acting as the "rotator cuff" of the hip joint [4]. Because of the inherent difficulties in inserting fine wire electrodes in these muscles, little knowledge is available to support these claims.

The functional interpretations of the EMG patterns found in the current study are based on the changing moment arms of the muscles that occur during hip flexion [5]. The internal/external rotation and adduction moment arms of the iliopsoas muscle are small relative to its hip flexion and pelvic tilt moment arms. Thus, it is likely that the iliopsoas acted mainly as an antagonist to the gluteal muscles to control pelvic tilt.

Pectineus activation was low during maximum hip flexion because it has an internal rotation moment arm similar to the gluteal muscles. However, the moment arms of the gluteal muscles change from internal rotation at deep flexion to external rotation as the hip approaches neutral extension in stance. The pectinueus muscle has an internal rotation moment arm thus activation becomes antagonist to the gluteal muscles as the body rises to standing. Thus, pectineus muscle activation increases as the gluteal muscles switch from internal rotation to external rotation but then diminishes near stance as the gluteal muscles relax.

The piriformis and gluteus medius muscles have moment arms that change from internal rotation at deep flexion to external rotation in stance. Thus these muscles performed as gluteal synergists during the squatting activity, acting concentrically during rising and eccentrically during lowering.

CONCLUSIONS

The piriformis and gluteus medius muscles are recruited to aid in hip extension during the squatting exercise. The activation of these muscles promotes posterior pelvic tilt and hip external rotation and abduction. To limit these accessory motions, the pectineus and iliopsoas muscles are recruited to produce anterior pelvic tilt, hip adduction and internal rotation. Thus, the deep muscles of the hip may have functioned as the "rotator cuff" of the hip joint to finely control pelvic and hip motions.

REFERENCES

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