Journal of Electromyography and Kinesiology 24 (2014) 489–496

Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

Insight into the function of the obturator internus muscle in humans: Observations with development and validation of an electromyography recording technique

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ARTICLE INFO

Article history:
Received 7 August 2013
Received in revised form 24 January 2014
Accepted 31 March 2014

Keywords:
Obturator internus
Electromyography
Ultrasound guidance
Hip stability
Hip external rotation

ABSTRACT

There are no direct recordings of obturator internus muscle activity in humans because of difficult access for electromyography (EMG) electrodes. Functions attributed to this muscle are based on speculation and include hip external rotation/abduction, and a role in stabilization as an "adjustable ligament" of the hip. Here we present (1) a technique to insert intramuscular EMG electrodes into obturator internus plus (2) the results of an investigation of obturator internus activity relative to that of nearby hip muscles during voluntary hip efforts in two hip positions and a weight-bearing task. Fine-wire electrodes were inserted with ultrasound guidance into obturator internus, gluteus maximus, piriformis and quadratus femoris in ten participants. Participants performed ramped and maximal isometric hip efforts (open kinetic chain) into flexion/extension, abduction/adduction, and internal/external rotation, and hip rotation to end range in standing. Analysis of the relationship between activity of the obturator internus and the other hip muscles provided evidence of limited contamination of the recordings with crosstalk. Obturator internus EMG amplitude was greatest during hip extension, then external rotation then abduction, with minimal to no activation in other directions. Obturator internus EMG was more commonly the first muscle active during abduction and external rotation than other muscles. This study describes a viable and valid technique to record obturator internus EMG and provides the first evidence of its activation during simple functions. The observation of specificity of activation to certain force directions questions the hypothesis of a general role in hip stabilisation regardless of force direction.

1. Introduction

Amongst leg muscles, few have been subject of as much speculation regarding their function as the deep lateral hip rotator muscles. This is particularly true for the obturator internus muscle, which, has been attributed functions as diverse as hip external rotation and abduction (Gray, 1989), hip stabilisation (regardless of direction of force) (O'Rahilly, 1986; Hall-Craggs, 1990), and provision of a stable attachment for the levator ani muscles (DeLancey, 1994). Anatomists have even attributed opposite actions (Basmajian and Slonecker, 1989). No recordings of electromyography (EMG) have been reported in humans.

Obturator internus is considered inaccessible for EMG recordings (Gray, 1989). Surface EMG is not appropriate for deep muscles and intramuscular electrode placement is difficult because of its small size and proximity to neurovascular structures (Stern and Larson, 1993). Placement of intramuscular electrodes is particularly challenging as much of the obturator internus bulk lies inside the pelvis. Consequently, even the simplest predictions regarding this muscle's function remain untested.

Obturator internus arises from the internal surface of the obturator membrane and the obturator foramen, then passes through the lesser sciatic foramen, underneath the sacrotuberous ligament, to the exterior of the pelvis and the lateral aspect of the greater trochanter of the femur (Gray, 1989). Based on predictions from anatomy (Gray, 1989) and EMG studies in apes (Stern and Larson, 1993), most texts define obturator internus as a hip external rotator and abductor, although adduction has also been proposed (Basmajian and Slonecker, 1989). The orientation of the deep hip lateral rotator muscles in parallel with the femoral neck is interpreted to suggest a role in hip stabilisation (O'Rahilly,

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http://dx.doi.org/10.1016/j.jelekin.2014.03.011
1050-6411/

1986; Hall-Craggs, 1990) to hold the femoral head in the acetabulum (Morris, 1953; Moore, 1985). Extensive levator ani muscle attachment to fascia overlying obturator internus implies a contribution to support of continence mechanisms (DeLancey, 1994; Hulme and Nevin, 1999). Clarification of the role(s) of the obturator internus muscle requires EMG recordings of obturator internus activity.

Here we describe a novel technique to insert intramuscular EMG electrodes into obturator internus in humans. We also aimed to validate the source of muscle activity recorded with the electrodes through comparison to the activity of surrounding muscles, and to investigate activity of the obturator internus in a range of maximal hip efforts in two hip positions, as its function may vary with hip angle (Dostal et al., 1986; Delp et al., 1999), and during simple functions.

2. Materials and methods

2.1. A method for insertion of intramuscular EMG electrodes into obturator internus

2.1.1. Anatomical considerations

Muscle fibres of obturator internus arise as a broad fan-like structure inside the pelvic cavity and narrow to a tendinous region as they pass externally to attach to the greater trochanter. The tendon is flanked by the inferior and superior gemmelli and is covered by gluteus maximus. The gemmelli originate from the external aspect of the ischium and attach to the obturator internus tendon (Shinohara, 1995). The region of the muscle accessible to recordings with less potential for crosstalk is that within the pelvis, away from the gemmelli. A technique was developed using ultrasound imaging to guide placement based on observation of cadavers.

2.1.2. Insertion technique

With the participant in prone the ischial tuberosity and sacrotuberous ligament are palpated and marked on the skin. Obturator internus is visualised with the ultrasound transducer placed along the sacrotuberous ligament (line between ischial tuberosity and sacrum [Fig. 1]) and the vascular structures are identified in cross-section (located medially and highlighted with colour Doppler ultrasound). The muscle abuts the ischial tuberosity as a triangular region with boundaries that move during hip external rotation. At this point the transducer is then rotated perpendicular to the sacrotuberous ligament to visualise the lesser sciatic notch, just proximal to the ischial tuberosity, where obturator internus passes in a pulley-like manner (Fig. 1). The muscle's identity is confirmed by visualisation of medial movement of the muscle over the sciatic notch with gentle external rotation of the hip. The transducer position is maintained and, after application of antiseptic, the needle is inserted medial to the transducer until the tip lies in the muscle's medial aspect (Fig. 1). Placement is confirmed by a burst of EMG activity during hip external rotation.

2.2. Validation of intramuscular EMG recordings from obturator internus

2.2.1. Participants

Ten healthy individuals (5 male, age – 31(8) years, height – 168 (9) cm, weight – 69(12) kg) volunteered. Participants were excluded if they had any known neurological conditions, any known clotting disorders, or current hip, pelvic or back pain. The local Health Sciences Research Ethics Board approved the study and all procedures were conducted in accordance with the Declaration of Helsinki. Participants provided written informed consent.

2.2.2. EMG recordings

EMG recordings were made on the right side for all participants. A commercial bipolar fine-wire EMG electrode (2 strands of insulated wire with 5 mm uninsulated tips bent back at 5 mm and 7 mm to form hooks; 50 mm × 25 gauge needle [Chalgren Enterprises Inc., USA] or custom-fabricated bipolar electrode [2 strands 75 μm Teflon coated stainless-steel wire, 1 mm Teflon removed, bent back at 1 and 3 mm to form hooks, 38 mm × 22 gauge hypodermic needle (Terumo, USA)]) was inserted into obturator internus. The type of electrode used depended on the depth of the obturator internus muscle as visualised using ultrasound imaging. A fine-wire electrode (custom-fabricated using 32 mm × 22 gauge hypodermic needle) was inserted into gluteus maximus 1 cm cranial to the obturator internus electrode. Fine-wire electrodes (either type) were inserted into other deep hip rotator muscles (quadratus femoris and piriformis) using standard sites similar to those reported for injection of local anaesthetic for piriformis (Smith et al., 2006) or standard clinical investigations for quadratus femoris (Lee and Delisa, 2000), again with the type of electrode was selected on the basis of the depth of these muscles from the skin surface. The additional muscle sites were selected for comparison of EMG activity of obturator internus against other hip external rotator muscles. EMG data were bandpass filtered between 20 and 2000 Hz, amplified 1000 times and sampled at 4000 Hz using a custom modified Bagnoli EMG system (Delsys, USA) and EMG-Works software (Delsys, USA).

2.2.3. Procedure

In prone with the knee flexed, participants performed slow ramped isometric contractions into external rotation against manual resistance in an attempt to elicit differential recruitment of the four hip external rotator muscles. Contractions ramped from rest to maximum over 4–7 s. Participants were encouraged to perform pure rotation without extension of the hip.

2.2.4. Data analysis

Recordings were compared qualitatively and quantitatively. Qualitative analysis involved inspection of relative onsets of EMG and patterns of EMG amplitude modulation. Quantitative analysis involved fitting a linear regression of obturator internus data plotted against that from the other muscles. EMG data for each muscle were high pass filtered at 50 Hz to remove movement artefact (Moseley et al., 2003), full-wave rectified and then low pass filtered at 10 Hz to create a linear envelope. The start and end of the ramp contraction were identified from obturator internus EMG. The period of contraction was divided into 25 epochs of equal duration and the root mean square (RMS) EMG amplitude was calculated for each. Separate regression lines were fitted to the epoch data for obturator internus and piriformis/quadratus femoris/gluteus maximus. Regression values, slopes and y-intercepts (latency between the two recordings) were recorded. Theoretically correlation coefficients between EMG channels near or equal to one, with concurrent intercept at or near zero would suggest that EMG was recorded from the same muscle whereas lower correlation coefficients and any significant deviation in the intercept would suggest that EMG activation was recorded from distinct muscles.

2.2.5. Statistical analysis

Regression values, slopes and y-intercepts for each regression line were compared between muscle pairs with a repeated measures analysis of variance (ANOVA).