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Changes in direction-specific activity of psoas major and quadratus lumborum in people with recurring back pain differ between muscle regions and patient groups

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ABSTRACT

Psoas major (PM) and quadratus lumborum (QL) muscles have anatomically discrete regions. Redistribution of activity between these regions has been observed in people with low back pain (LBP). We hypothesised that the bias of activity of specific regions of PM and QL towards trunk extension may change depending on whether LBP individuals have more or less erector spinae (ES) activity in an extended/upright lumbar posture. Ten volunteers with recurring episodes of LBP and nine pain-free controls performed isometric trunk efforts in upright sitting. LBP individuals were subgrouped into those with high and low ES electromyographic activity (EMG) when sitting with a lumbar lordosis. Fine-wire electrodes were inserted into fascicles of PM arising from the transverse process (PM-t) and vertebral body (PM-v) and anterior (QL-a) and posterior layers (QL-p) of QL. The LBP group with low ES EMG had greater bias of PM-t, PM-v and QL-p towards trunk extension. The LBP group with high ES activity showed less PM activity towards extension. These findings suggest redistribution of activity within and/or between these muscles with extensor moments. This is likely to be important to consider for effective clinical interventions for individuals with LBP.

1. Introduction

Psoas major (PM) and quadratus lumborum (QL) have complex anatomy (Bogduk et al., 1992; Phillips et al., 2008) with anatomically discrete regions that can be activated differentially in a manner predicted from their biomechanics. Fibres situated posterior to the instantaneous centre of rotation of the lumbar segments are preferentially activated in tasks that involve spine extension such as isometric trunk extension efforts in upright sitting (Park et al., 2012) or adoption of a lumbar lordosis (Park et al., 2013). Recent work quantified the activation of discrete regions of these muscles during submaximal isometric contractions across of range of directions in sitting (Park et al., 2012). Although regional pattern of activation appears relatively consistent between individuals, there is preliminary evidence (published as an abstract) that the direction of force production in which the PM and QL muscles are most active, often referred to as the preferred direction for activation, may differ between healthy individuals and some subgroups of people with low back pain (LBP) (Park et al., 2011). However, in that study, the preferred direction was inferred from activation with changes in activation of the muscles with changes in spinal extension posture in sitting. That study cannot provide insight into whether the preferred direction of activation was changed (as has been reported for other muscles in people with pain (Lindstrom et al., 2011)) or whether it is simply a change in the pattern of activity used to adopt specific sitting postures.

Consistent with biomechanical predictions, activity of posteriorly situated fascicles of PM that arise from transverse processes (PM-t) is greater when torque is generated towards extension than flexion, whereas that of PM fascicles, arising from the vertebral body (PM-v), is greater towards trunk flexion (Park et al., 2012). Such differentiation of PM activity is also reflected in changes in its activity recorded in sitting; activity of PM-t, but not PM-v, increases when the lumbar lordosis is increased (Park et al., 2013). Similarly, activity of posterior fascicles of QL (QL-p) is greater during trunk extension and lateral-flexion than other directions, whereas activity of the anterior QL fascicles (QL-a) is greater in a pure lateral-flexion direction than extension (Park et al., 2013). Like numerous other trunk muscles (Hides et al., 1994; Hodges and Richardson, 1996, 1998; MacDonald et al., 2009), activation of PM and QL has been suggested to change in LBP (Barker et al., 2004; Dangaria and Naesh, 1998; De Franca and Levine, 1991; Hides et al., 2008; Travell and Simons, 1983) and this may be reflected by changes in the preference for activation in specific

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directions, as has been shown for transversus abdominis (TrA) (Ferreira et al., 2004; Hodges and Richardson, 1996, 1998).

Although activation of PM and QL to maintain sitting is similar for LBP patients and controls when the patients are considered as a single homogeneous group, this is not the case when patients are divided into those who show low and high amplitudes of erector spinae (ES) EMG to maintain upright sitting (Park et al., 2011). LBP patients with low ES have greater PM-v and QL-p EMG (normalised to maximum voluntary contraction) than pain-free individuals and LBP patients who have high ES activity when sitting with a flat back. When sitting with a lumbar lordosis, LBP patients with high ES EMG have less PM-v and PM-t activity than those with low ES (Park et al., 2011). Taken together, these data imply that the bias for PM and QL activation towards trunk extension may increase or decrease depending on subgroups of LBP patients. On the basis of the preliminary data of changes in activation in upright sitting (Park et al., 2011), we hypothesised that people with LBP who rely less on activation of ES to maintain their extended/upright lumbar posture may change the preferred direction of activation of PM and QL to have a greater bias towards trunk extension, with less activation in other directions. Conversely, individuals who rely more on the ES may have activation of PM and QL that is more evenly distributed across directions, with less bias to extension. One way to test this hypothesis is to compare activation patterns for PM and QL during submaximal isometric trunk efforts across of a range of directions. This study aimed to use this method to compare activation of regions of PM and QL in people subgrouped into those with low and high activation of ES in upright sitting, and to compare this with data from a previous group of pain-free controls.

2. Methods

2.1. Participants

Ten volunteers (mean [standard deviation] age: 23 [4] years, height: 171 [11] cm, and mass: 67 [12] kg; six male) with recurring episodes of LBP (multiple episodes of LBP separated by periods of remission) participated in this study. Data were compared with those for twelve healthy control participants (24 [2] years, 169 [5] cm, and 65 [12] kg; nine male) with no history of LBP, who participated in an earlier study (Park et al., 2012). Participants in the recurrent LBP group were included if they had experienced an initial episode of LBP (symptoms from T12 to the gluteal fold) more than 12 months prior to inclusion with subsequent bouts of LBP, that were severe enough to limit activities of daily living and/or to take time off from work and/or sports and separated by the periods of pain-free remission. Participants were pain-free at the time of testing and were excluded from both groups if they reported any major circulatory, cardiorespiratory, orthopaedic or neurological conditions or if they had any history of back or abdominal surgery. All procedures were approved by the Institutional Medical Research Ethics Committee and were conducted in accordance with the Declaration of Helsinki.

2.2. Electromyography

EMG activity of PM and QL was recorded with intramuscular fine-wire bipolar electrodes (Teflon-coated 75 μm stainless steel wire, 1 mm of Teflon removed, threaded into a hypodermic needle [0.70 × 150 mm for PM and 0.65 × 70 mm for QL], and bent back to form 1 and 2 mm hooks). Electrodes were inserted into right PM-t, PM-v, QL-a and QL-p at the L3-4 level with ultrasound guidance (GE Medical, USA), using a previously described protocol (Park et al., 2012). Anatomy of different regions of each muscle was confirmed from preliminary investigation on cadavers and ultrasound examination on healthy volunteers. The middle layer of QL was not investigated because of difficulty with identification of its fibres from the other QL layers. Pairs of surface electrodes (Ag/AgCl discs, 10 mm in diameter, Noraxon, USA) were placed over right ES, 2 cm lateral to the L4 spinous process (Cholewicki et al., 1997), and over right OE and OI/TrA (Ng et al., 1998). A ground electrode was placed over right anterolateral aspect of the caudal rib cage.

EMG data were amplified 2000 times, band-pass filtered between 10 Hz and 1.5 kHz (TeleMyo telemetered EMG system; Noraxon, USA) and then further high pass filtered at 30 Hz to remove any movement artefacts, and sampled at 2 kHz using a Power 1401 Data Acquisition System with Signal3 software (Cambridge Electronic Design, Cambridge, United Kingdom).

2.3. Procedure

2.3.1. Trunk loading task

Participants sat upright in a semi-seated position with the pelvis fixed and the lower limbs secured with padded supports (Park et al., 2012). Participants wore a harness over the shoulders from which cables were attached at the front, back and sides at the T9 level. In separate trials, weights (15% body mass) were attached to cables that passed through low-friction pulleys to exert force in one of eight directions (Fig. 1A). To load in the sagittal and frontal plane, mass was attached to the back (Flexion), front (Extension; Fig. 1B), or left or right sides of the harness (Right and Left Lateral-flexion, respectively). To load the diagonal force directions

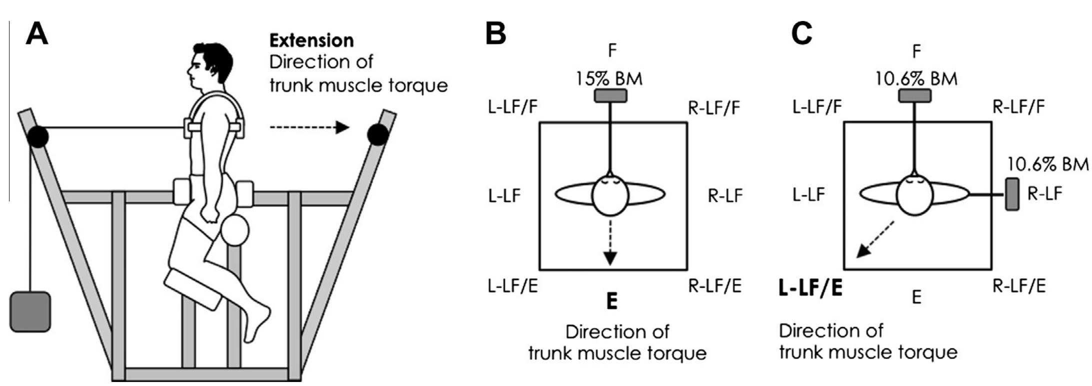

Fig. 1. (A) Experimental setup. The pelvis and legs were stabilised in the custom made device. Upright posture was maintained when load (15% of body mass in total) was applied to exert a horizontal force in specific directions. Dashed arrow indicates direction of trunk muscle torque. (B) Anterior load required isometric trunk torque to maintain the upright posture, defined as extension (E). (C) Anterior and lateral (right) load required isometric trunk torque towards left lateral-flexion/extension (L-LF/E). R, right; L, left; F, flexion; LF/F, lateral-flexion/flexion; LF, lateral-flexion; LF/E, lateral-flexion/extension; E, extension; BM, body mass.