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Lumbopelvic flexibility modulates neuromuscular responses during trunk flexion–extension

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ABSTRACT

Various stimuli such as the flexibility of lumbopelvic structures influence the neuromuscular responses of the trunk musculature, leading to different load sharing strategies and reflex muscle responses from the afferents of lumbopelvic mechanoreceptors. This link between flexibility and neuromuscular response has been poorly studied.

The aim of this study was to investigate the relationship between lumbopelvic flexibility and neuromuscular responses of the erector spinae, hamstring and abdominal muscles during trunk flexion–extension. Lumbopelvic movement patterns were measured in 29 healthy women, who were separated into two groups according to their flexibility during trunk flexion–extension. The electromyographic responses of erector spinae, rectus abdominis and biceps femoris were also recorded.

Subjects with greater lumbar flexibility had significantly less pelvic flexibility and vice versa. Subjects with greater pelvic flexibility had a higher rate of relaxation and lower levels of hamstring activation during maximal trunk flexion.

The neuromuscular response patterns of the hamstrings seem partially modulated by pelvic flexibility. Not so with the lumbar erector spinae and lumbar flexibility, despite the assertions of some previous studies. The results of this study improve our knowledge of the relationships between trunk joint flexibility and neuromuscular responses, a relationship which may play a role in low back pain.

1. Introduction

Movements involving trunk flexion–extension are common during everyday activities, occupational demands and sports, and show a high frequency of associated injuries, which in turn have been linked to disruptions in spinal tissue neuromuscular balance and load sharing (Colloca and Hinrichs, 2005). Therefore, improving our knowledge of the biomechanics of trunk flexion–extension is of great clinical importance.

Trunk flexion–extension is an interaction between intervertebral and pelvic joints known as lumbo-pelvic rhythm (Cailliet, 1994) which is associated with specific patterns of muscle activation. An eccentric contraction of the erector spinae muscles (ES) controls spinal flexion, whereas the eccentric contraction of hip extensors (glutei, hamstrings) controls pelvic flexion. At some point during trunk flexion, ES activity suddenly ceases: this is called the flexion–relaxation phenomenon (FRP) (Floyd and Silver, 1955). Numerous studies have shown that FRP is a consistent and predictable response in most normal subjects without lower back pain (LBP) (Mayer et al., 2009).

FRP occurs between 75% and 85% of maximum trunk flexion (Mayer et al., 2009; Neblett et al., 2003); when FRP starts, lumbar flexion is almost complete, and the potential for even more pelvic flexion remains. Maximum lumbar flexion is achieved first, and from then on maximum trunk flexion occurs exclusively by means of an increase in pelvic flexion, controlled by the glutei and hamstrings (Sihvonen, 1997).

FRP also occurs in hamstrings during terminal pelvic flexion. Hamstring electromyographic (EMG) activity ceases at 97% of maximum lumbar flexion. From this point on, maximum trunk flexion is achieved with no activity of the spinal and pelvic muscles. During extension, both muscles activate concentrically: the hamstrings activate first, followed by the ES (Sihvonen, 1997).

At the end of trunk flexion, the abdominal muscles, rectus abdominis (RA) and oblique muscles, show a unique burst of activation (Paquet et al., 1994). Contraction of the abdominal muscles contributes to maintaining spinal flexion in the sagittal plane, without

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allowing lateral deviations, and can also participate in an active attempt to increase maximum trunk flexion (Bogduk, 2005; Paquet et al., 1994).

The spinal stabilizing system described by Panjabi (1992) encompasses the actions of all these structures. It consists of three subsystems: (a) passive (vertebrae, intervertebral discs, ligaments and fascia), (b) active (muscles and tendons) and (c) the neural control unit. In a normal state the three subsystems work together to provide sufficient stability to the spine to match the instantaneously varying stability demands due to changes in spinal posture, and static and dynamic loads. The neural control unit estimates the stability demands and consequently adjusts individual muscle tension according to variations of lever arms and inertial loads of different masses, and external loads (Hashemirad et al., 2009; Panjabi, 1992).

Passive structures are deformed, which generates information from the mechanoreceptors contained within them; this information generates muscle activation or relaxation responses (Holm et al., 2002). Different authors have studied the relationship between the viscoelastic properties of passive spinal tissues, neuromuscular responses, and even potential mechanisms of spinal damage. Solomonow et al. (1999) observed that the creep induced in viscoelastic tissues by the application of repeated loading causes desensitization of mechanoreceptors, which in turn causes a significant decrease in muscle activation and thus greater exposure to instability and possible injury. Other studies (Sánchez-Zuriaga et al., 2010) have observed that after inducing creep, and the consequent increase in passive structure compliance, there is a marked delay in reflex lumbar muscle activation.

In general, these kinds of studies emphasize the negative effect of reducing the spinal rigidity, which results in increased compliance and alters neuromuscular responses. This may be related to the mechanisms of back injury during activities involving trunk flexion.

Changes in the distensibility of elastic structures have also been associated with changes in neuromuscular activity of lumbopelvic muscles and trunk motion patterns. Hashemirad et al. (2009) observed that individual flexibility and angles of trunk and knee flexion have a significant effect on the flexion–extension responses of spinal extensor muscles. They found that in subjects with greater flexibility the ES relaxed later during flexion, i.e. at greater angles of spinal and pelvic flexion, and that they reactivated before extension starts, i.e. they had a shorter FRP. These changes were thought to be caused by a transfer of the stabilizing action to the active components in more flexible subjects, whereas in subjects with less flexibility passive structures would have a greater role in the control of movement. It therefore seems to be a relationship between measures of flexibility, such as lumbar and pelvic flexion angles in maximum trunk flexion, and muscle activity patterns. This interdependence between individual flexibility and neuromuscular response patterns may explain, for example, the increased likelihood that patients with hypermobility syndrome have of suffering from musculoskeletal injuries, which is caused by tissue laxity and the corresponding decrease in proprioceptive acuity and alteration of neuromuscular reflexes (Simmonds and Keer, 2007). In fact, Greenwood et al. (2011) found differences in muscle activation patterns between normal subjects and those with joint hypermobility, which specifically affect hip and pelvis muscles. The increased risk of injury of these patients has been linked to these altered muscle stabilization strategies.

None of the previous studies on the effect of individual flexibility in trunk neuromuscular activation patterns has simultaneously analyzed the activity patterns of the ES, hamstring, and abdominal muscles during a dynamic trunk flexion–extension task. Therefore the purpose of this study is to investigate the relationship between individual flexibility and the ES, hamstring, and abdominal muscles EMG activity pattern during a dynamic trunk flexion–extension maneuver. The study hypothesis is that lumbar spine and pelvic flexibility could influence the trunk muscle activity pattern during a flexion–extension task. In this scenario the viscoelastic structures of more flexible subjects would be able to elongate to a greater degree, and this could cause different neuromuscular responses and movement patterns between more or less flexible subjects.

2. Materials and methods

2.1. Subjects

29 healthy women, none of whom suffered from back pain at the time of the study or recounted a history of lower back pain, participated in the study. Their age and anthropometric characteristics are summarized in Table 1.

Written consent to participate in the investigation was obtained from the subjects after they had been informed about the study, and an institutional ethical review board (Human Research Ethics Committee, Universitat de València, València, Spain) approved the project. All the procedures were conducted in accordance with the principles of the World Medical Association's Declaration of Helsinki (Rickham, 1964).

2.2. Instrumentation

The angular displacement of the lumbar spine and pelvis in the sagittal plane was recorded using a Liberty 240/16 electromagnetic motion capture system (Polhemus Inc., Colchester, USA). This apparatus uses a low frequency magnetic field generated by an electromagnetic source, which is placed in a plastic platform adjusted at hip level for each participant. Two sensors detect the magnetic pulses, with a sampling frequency of 240 Hz. The first sensor (L1) is attached to the skin overlying the spinous process of the first lumbar vertebra, and provides data on the displacement of the trunk as a whole (lumbar and pelvis). The second sensor (S1) is placed at the level of the first sacral vertebra, and provides data on the inclination of the sacrum at the coxofemoral joint (pelvic flexion) (Mayer et al., 1984). Subtracting the S1 data from the L1 data gives the true lumbar spine motion (Neblett et al., 2003).

The EMG activity was recorded by three EMG100C Biopac modules (Biopac Systems, Inc., Goleta, CA), using pre-gelled disposable silver–silver chloride (Ag/AgCl) surface disk electrodes (2 cm diameter). Prior to EMG electrode placement, the registration points of the activity of each muscle were located following the recommendations of the Surface Electromyography for Non-Invasive Assessment of Muscles (SENIAM) project (Hermens et al., 2000). The RA was located 3 cm to the right of the navel; the hamstrings (biceps femoris, BF) electrodes were placed at the midpoint of the distance between the right ischial tuberosity and the fibular head. The ES EMG signal was recorded at the third lumbar vertebra, with electrodes placed 3 cm to the right of the spinous process. A reference electrode was placed at the level of the sternal body. After carefully cleaning and lightly abrading the skin with an alcohol pad, two recording electrodes were attached on each registration point, parallel to the underlying muscle fibers, with a center-to-center distance of 2 cm. The raw EMG signal was band-pass filtered (cutoff frequencies: 10 Hz high pass, 500 Hz low pass) and amplified (input impedance greater than 100 MΩ, common mode rejection ratio of 110 dB at 60 Hz, overall gain of 1000). EMG signals were A/D converted at a sampling

Table 1
Age and anthropometric measurements.

n	Age (years)	Weight (kg)	Height (m)	Body mass index (kg/m^2)
29	30 ± 4	60.3 ± 8.5	1.7 ± 0.1	22.4 ± 3.0