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Balance of hip and trunk muscle activity is associated with increased anterior pelvic tilt during prone hip extension

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ABSTRACT

Prone hip extension has been used as a self-perturbation task to test the stability of the lumbopelvic region. However, the relationship between recruitment patterns in the hip and trunk muscles and lumbopelvic kinematics remains unknown. The present study aimed to examine if the balance of hip and trunk muscle activities are related to pelvic motion and low back muscle activity during prone hip extension. Sixteen healthy participants performed prone hip extension from 30° of hip flexion to 10° of hip extension. Surface electromyography (of the gluteus maximus, semitendinosus, rectus femoris, tensor fasciae latae, multifidus, and erector spinae) and pelvic kinematic measurements were collected. Results showed that increased activity of the hip flexor (tensor fasciae latae) relative to that of hip extensors (gluteus maximus and semitendinosus) was significantly associated with increased anterior pelvic tilt during hip extension ($r = 0.52$). Increased anterior pelvic tilt was also significantly related to the delayed onset timing of the contralateral and ipsilateral multifidus ($r = 0.57$, $r = 0.53$) and contralateral erector spinae ($r = 0.63$). Additionally, the decrease of the gluteus maximus activity relative to the semitendinosus was significantly related to increased muscle activity of the ipsilateral erector spinae ($r = -0.57$). These results indicate that imbalance between the agonist and antagonist hip muscles and delayed trunk muscle onset would increase motion in the lumbopelvic region.

1. Introduction

Active prone hip extension is often used as an exercise in physical therapy for the patients with hip or trunk dysfunction. This task also has been used as a self-perturbation task to test the stability of the lumbopelvic region (Janda, 1996; Sahrmann, 2002). Clinically, in patients with lumbopelvic dysfunction, the lumbopelvic region is often observed to extend or rotate excessively during prone hip extension (Sahrmann, 2002).

Previous studies have analyzed muscle activation patterns with respect to muscle firing order during active prone hip extension. Vogt and Banzer (1997) studied the sequential activation of lumbar and hip muscles in active prone hip extension. They found that there is a consistent muscle firing order of the ipsilateral lumbar erector spinae, semitendinosus, contralateral lumbar erector spinae, tensor fasciae latae, and gluteus maximus. Sakamoto et al. (2009) also reported the muscle activation order of the semitendinosus, ipsilateral and contralateral erector spinae, and gluteus maximus muscles in prone hip extension with knee flexion, knee extension, and hip lateral rotation and knee flexion. However, other studies indicated that there are no consistent recruitment patterns for prone hip extension among erector spinae, hamstrings, and gluteus maximus (Lehman et al., 2004; Pierce and Lee, 1990). Moreover, a report by Guimarães et al. (2010) has cast doubt over the possibility that patients with low back pain and the healthy individuals can be distinguished only by analyzing the muscle firing order. This study suggested that it is necessary to evaluate the movement patterns in addition to the muscle activation patterns during the active prone hip extension in order to discriminate between patients with low back pain and healthy individuals (Guimarães et al., 2010).

The factors affecting the lumbopelvic kinematics and activity of the low back muscles during hip extension could include muscle activity balance in the hip-joint muscles (balance between agonist and antagonist muscles as well as balance among the synergistic muscles) and muscle activity balance between the hip and trunk muscles (balance between the prime mover and lumbopelvic stabilizer). It is theoretically possible that altered balance of muscle activation amplitudes and muscle activation timing leads to altered movement patterns, favoring the occurrence of anterior pelvic tilt and excessive lumbar extension. However, no studies have examined the relationship between the balance in hip and trunk muscle activity and kinematic or muscle activity in the lumbopelvic region.

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The purpose of this study was to examine if the balance of hip and trunk muscle activities are related to pelvic motion and low back muscle activity during prone hip extension. By examining these relationships, we will gain insights into the potential cause of lumbopelvic pathokinematics during prone hip extension.

2. Methods

2.1. Participants

Sixteen healthy subjects (10 men and 6 women) participated in the study. Their mean age was 24.3 ± 5.2 (mean ± SD) years, their mean body weight was 59.0 ± 8.0 kg, and their mean height was 165.7 ± 7.9 cm.

Subjects were excluded from the study if they had musculoskeletal conditions, or if they had been diagnosed with neurological disorders or cardiovascular disease that would limit their function. Subjects who had a hip extension angle less than 10° were also excluded from the study. All of the subjects provided informed consent, and the protocol was approved by the Ethics Committee of the Kyoto University Graduate School and Faculty of Medicine.

2.2. Experimental procedure

The subjects were asked to lie on a table in the prone position with the right hip hanging over the edge of the table which was tilted down to 30°. Each subject was instructed to perform active hip extension from 30° of flexion to 10° of extension while keeping the knee extended. For each subject, the hip extension angle was defined by placement of a thin rope (Fig. 1). Fixation devices were not applied to the pelvis and trunk. The subjects raised the leg for 1 s after an LED indicator signal placed in front of the subjects was turned on. The hip was held in the extended position for at least 3 s. Prone hip extension was performed for five consecutive repetitions.

2.3. Electromyography recording and data analysis

After the electrode sites were shaved and cleaned with scrubbing gel and alcohol, disposable pre-gelled electromyography (EMG) Ag–AgCl electrodes (Blue sensor; Medicotest Inc., Olstykke, Denmark) with a 2-cm center-to-center inter-electrode distance were applied over the following eight muscles according to the SENIAM recommendations (SENIAM Web site): the bilateral lumbar erector spinae (ES: at a 2-finger-width distance lateral from the spinous process of L1), bilateral lumbar multifidus (MF: at the level of the L5 spinous process on a line extending from the posterior superior iliac spine to the interspace between L1 and L2), right gluteus maximus (Gmax: 50% on the line extending between the sacrum and greater trochanter), right semitendinosus (ST: 50% on the line extending between the ischial tuberosity and medial epicondyle), right rectus femoris (RF: 50% on the line extending from the anterior superior iliac spine to the superior part of the patella), and right tensor fasciae latae (TFL: on the line extending from the anterior superior iliac spine to the lateral femoral condyle in the proximal 1/6). All electrode placements were confirmed through palpation and manual resistance. Raw EMG signals processed using an 8th-order Butterworth filter with a bandpass range of 10–500 Hz (CMR >100 dB) were amplified and collected with a sampling rate of 1000 Hz using a 12-bit A/D converter with a ±5-V range (Telemyo 2400T V2; Noraxon USA Inc., Scottsdale, AZ). Manual resistance was applied to obtain maximal voluntary isometric contractions (MVICs) in the following positions: prone trunk extension for the trunk extensors, prone hip extension with knee flexion for the gluteus maximus, prone knee flexion for the semitendinosus, sitting knee extension for the rectus femoris, and sidelying hip abduction for the tensor fasciae latae. Subjects were instructed to generate muscle contraction force against the resistance, while the EMG signals were recorded during a stable 3 s as MVICs for each muscle.

The root-mean-squares (RMSs) of the raw data were determined, and 3-s MVICs were calculated for each muscle. For each individual muscle, the average RMS EMG amplitude was determined over the 3-s period, while the leg was maintained in the hip-extended position. The average RMS EMG amplitude of the each muscle was normalized to each of the MVICs. According to previous studies, a positive EMG signal was designated >5% MVICs (Potvin and O'Brien, 1998; Ricamato and Dhaher, 2004; Zhang et al., 2009). Furthermore, after normalization, we calculated (RF × 2)/(Gmax + ST), (TFL × 2)/(Gmax + ST), and Gmax/ST to index the balance of hip muscle activity, and (contralateral MF × 2)/(Gmax + ST), (ipsilateral MF × 2)/(Gmax + ST), (contralateral ES × 2)/(Gmax + ST), and (ipsilateral ES × 2)/(Gmax + ST) to index the balance of hip and trunk muscle activity.

The onset of the muscle activity was determined using the cumulative sum (CUSUM) methods (Ando et al., 2009; Brodin et al., 1993). First, we rectified EMG from 500 ms before the LED signal to 1000 ms after the LED signal. Second, the background EMG over 500 ms before the LED signal were averaged. The mean background EMG was subtracted from the rectified EMG. The rectified EMG was summed up over 1000 ms after the LED signal, and the resulting value was defined as 100%. The EMG onset was defined as the point at which the cumulative sum of the rectified EMG reached a threshold of 5%. When we judged that the EMG onset was not appropriate by visual inspection, we changed the threshold with a step of 0.1%. The EMG onset time was determined by a single blinded investigator. In order to investigate the temporal firing pattern among the hip and trunk muscles, the relative difference of the onset time between each muscle and the prime mover (the semitendinosus) was calculated (Chance-Larsen et al., 2010; Lehman et al., 2004). A positive value indicates that the semitendinosus muscle was getting activated earlier.

For the normalized RMS EMG amplitude and relative time difference of each muscle, the averages of the values obtained in the five repetitions were determined for subsequent analysis.

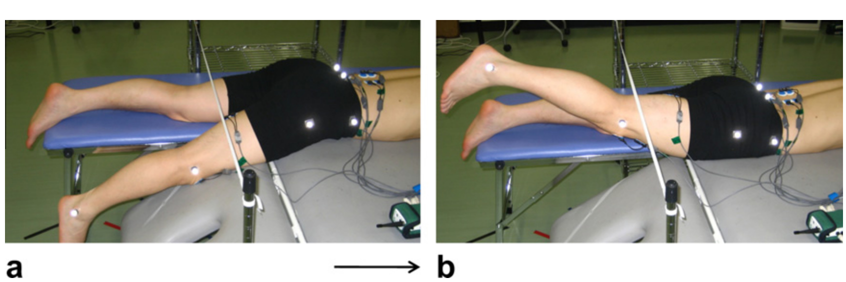

Fig. 1. Active prone hip extension from the 30° hip-flexed position (a) to the10° hip-extended position (b).