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Pelvic instability and trunk and hip muscle recruitment patterns in patients with total hip arthroplasty

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ABSTRACT

Hip and lumbar spine disorders often coexist in patients with total hip arthroplasty (THA). The current study aimed to reveal pelvic motion pathology and altered trunk and hip muscle recruitment patterns relating to pelvic motion in patients with THA. Twenty-one women who underwent THA and 12 age-matched healthy women were recruited. Pelvic kinematics and muscle recruitment patterns (i.e., amplitude, activity balance, and onset timing) of the gluteus maximus, semitendinosus, multifidus, and erector spinae were collected during prone hip extension. Compared with healthy subjects, the patients showed increased pelvic motion, especially ventral rotation, decreased multifidus muscle activity relative to the hip extensors, and delayed onset of multifidus activity, despite reaction times and speeds of leg motion not being significantly different between the groups. Furthermore, while contributing factors associated with ventral pelvic rotation were not found, delayed onset of multifidus activity was detected as a factor related to the increased anterior tilt of the pelvis ($r = 0.47$, $p < 0.05$) in patients with THA. These results suggest that patients with THA have dysfunction of the stabilizer muscles of the lumbopelvic region along with increased pelvic motion.

1. Introduction

Hip and spine disorders commonly coexist in patients with hip osteoarthritis (McNamara et al., 1993; Stupar et al., 2010), and low back pain is reported by up to 49.4% of these patients (Parvizi et al., 2010). This pathological condition has been described as the hip–spine syndrome (Offierski and MacNab, 1983); restoration of hip biomechanics by total hip arthroplasty (THA) often resolves the related low back pain or lumbar spine disorders (Ben-Galim et al., 2007; Parvizi et al., 2010). However, Parvizi et al. (2010) showed that lumbar pain persists in 33.5% of patients, even after THA. Interestingly, those patients with low back pain included patients who did not have preexisting spinal diseases, suggesting that patients undergoing THA with no apparent spinal disease are at risk for lumbopelvic disorders. Importantly, THA patients with lumbar spine disorders experience less improvement in hip pain and functional scores from the postoperative therapy, and cost the healthcare system about 1.4 times as much, compared to patients with THA alone (Prather et al., 2012).

Patients with limited ranges of hip motion and those having had THA tend to compensate by altering their lumbopelvic motion (Miki et al., 2004), which may result in the establishment of movement patterns associated with increased lumbopelvic motion. Hu et al. (2010) showed that adjunctive lumbopelvic stability using a pelvic belt results in less strain on hip muscles during leg raise compared with the motion without a pelvic belt, suggesting that lumbopelvic stability facilitates efficient use of hip muscles in addition to preventing destabilization of the lumbopelvis. Therefore, detailed evaluation and appropriate treatment for pathokinesiology of the hip and lumbopelvic region is a key consideration for patients following THA, regardless of the presence of low back pain.

Lumbopelvic instability has been assessed from two standpoints: mechanical and functional instability (Beazell et al., 2010; Panjabi, 2003). Mechanical instability is considered to be related to an increase in end range of motion assessed by imaging findings, including X-rays and magnetic resonance imaging, while functional instability appears to be related to a loss of segmental stiffness and mid-range segmental neuromuscular control during motion (Beazell et al., 2010). Functional instability has been evaluated by observing altered lumbopelvic motion during trunk and lower limb

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movements. In this study, we defined lumbopelvic instability (functional instability) as excessive motion and unsustainability of optimal alignment in the lumbopelvic region, compared with the motion and lumbopelvic alignment shown by healthy individuals, during lower limb movement.

Successful treatment of lumbopelvic instability is difficult, in part, because the pathology of the muscle recruitment patterns (i.e., amplitude, activity balance, and onset timing) and the relationship between altered muscle activity and the pelvic motion are not completely understood. Thus, the purposes of this study were (1) to reveal changes in pelvic motion and trunk and hip muscle activity in patients with THA and (2) to determine the relationship between pelvic motion and muscle recruitment patterns within patients with THA. The results of this study offer insight into treatment for lumbopelvic instability in patients with THA.

2. Methods

2.1. Participants

Twenty-one women, who underwent THA at least 6 months prior to the study, were recruited. Their mean age was 62.5 ± 6.6 (mean ± SD) years; with a mean body weight of 50.1 ± 6.5 kg; and an average height of 152.7 ± 4.4 cm. Since pain affects feedforward muscle activity and movement strategies (Dubois et al., 2011; Hodges et al., 2003), patients without hip pain were recruited. All patients had undergone THA due to painful hip osteoarthritis, and surgery had occurred, on average, 32.5 ± 12.1 months prior to the study. The average Harris hip score of the patients was 85.8 ± 11.5 (100 point maximum). Patients were excluded from the study if they had musculoskeletal conditions other than THA or if they had been diagnosed with neurological disorders. Twelve additional women, matched for age (63.3 ± 5.1 years), weight (50.4 ± 5.5 kg), and height (152.3 ± 5.0 cm), were also recruited; these control individuals were free from orthopedic and neurologic abnormalities. Participants provided informed consent, and the Institutional Ethics Committee approved the study.

2.2. Experimental procedure

Prone hip extension, commonly used as a self-perturbation task to test the lumbopelvic stability (Janda, 1996; Sahrmann, 2002), was used in this study. The participants 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° (Fig. 1). Each participant was instructed to perform active hip extension from 30° to 0° of hip flexion while keeping the knee extended; fixation devices were not applied to the pelvis or trunk. Movement during each trial started after a verbal ready signal followed by a random visual cue using two (right and left) light-emitting diodes (LED) set in front of the participants. The illumination of one of the LEDs indicated which leg the subject should raise. The participants were instructed to perform the task as rapidly as possible in response to the visual cue. Several practices were allowed, prior to testing, to familiarize the participants with the required movements. For the patients with THA, five tasks with the affected leg were included in the analysis; for the controls, five tasks with the nondominant leg (i.e., the leg opposite to the one the subjects would use for kicking a ball) were included. To avoid comparison with superior members, we adopted the nondominant leg in healthy individuals as control.

2.3. Kinematic measurements

Pelvic kinematics data were recorded using a Vicon Nexus (Vicon Motion System Ltd., Oxford, England) with six cameras operating at a sampling frequency of 200 Hz. The subjects were clothed in close-fitting shorts and T-shirts, with seven light-reflecting markers attached to anatomical landmarks on the bilateral posterior superior iliac spine, top of the iliac crest, right greater trochanter, lateral epicondyle of the femur, and lateral malleolus (Fig. 1). All data were low-pass filtered using a Woltring filter with a cut-off frequency of 6 Hz.

Three-dimensional (3D) angular displacements (tilt, oblique, and rotation) of the pelvis were calculated over time (Fig. 1). To standardize the analytical range among participants, 3D angles of the pelvis were calculated as the changes from the angle in the initial prone position to the angle at which the knee marker reached 75% of the height of the initial position of the greater trochanter marker.

In addition to the amount of the pelvic angle change during movement, onset timing of the pelvic motion was determined. The onset of the pelvic motion was defined as the time at which the angular velocity of the anterior pelvic tilt exceeded 5% of the maximal angular velocity. The initiation of the leg motion was defined as the point at which the upward velocity of the marker on the lateral femoral epicondyle exceeded 5% of the maximal velocity (Scholtes et al., 2009) (Fig. 2). We used a method with relative

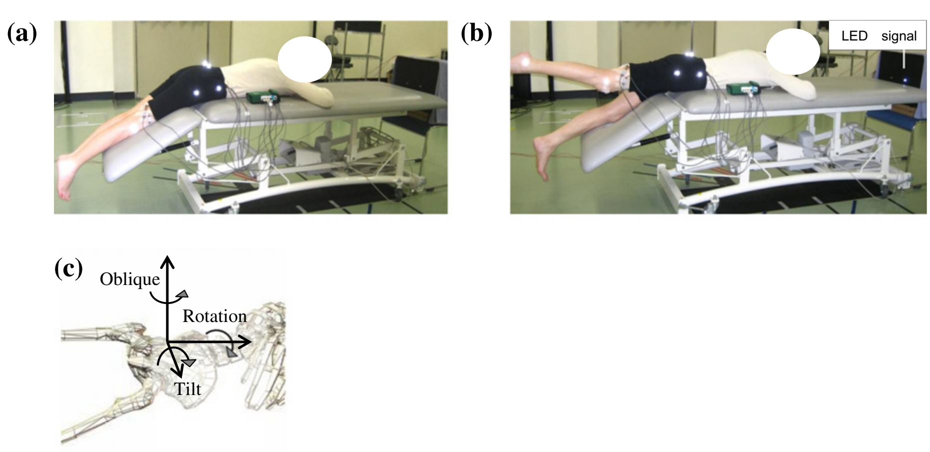

Fig. 1. Active prone hip extension from the 30° (a) to the 0° hip-flexed position (b). Each participant was instructed to move as rapidly as possible in response to the LED signal. Markers were attached on the bilateral posterior superior iliac spine, top of the iliac crest, unilateral greater trochanter, lateral epicondyle of the femur, and lateral malleolus. Tilt, oblique, and rotation of the pelvis were calculated (c).