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Original research

Comparison of gluteus maximus and hamstring electromyographic activity and lumbopelvic motion during three different prone hip extension exercises in healthy volunteers

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ABSTRACT

Objective: To compare the surface electromyography (EMG) amplitude of the hip joint, including the gluteus maximus (GM), biceps femoris (BF), and semitendinosus (ST) muscles generated by three different exercises: prone hip extension (PHE), prone table hip extension (PTHE), and prone table hip extension with 90° knee flexion (PTHEK), with compensatory pelvic motions.
Design: Repeated-measure within-subject intervention.
Participants: Sixteen-healthy males (mean age = 23.4 ± 2.2 years).
Main outcome measures: EMG was used to collect EMG signals from the GM, erector spinae (ES), BF, and ST muscles. Furthermore an electromagnetic tracking motion analysis was also performed to measure the compensations.
Results: EMG amplitude differed significantly among the three conditions (PHE vs. PTHE vs. PTHEK) ($p < 0.05$). The mean GM muscle activity increased significantly during the PTHEK (70.93% and 13.75% increases in %MVIC compared with the PHE and PTHE, respectively) ($p < 0.01$). However, there was no significant difference in the kinematic data for rotation or anterior tilting angle of the pelvis among the three conditions ($p > 0.05$).
Conclusions: These results suggest that the PTHEK can be recommended as an effective method to strengthen the GM muscle without increased BF or ES muscle activities and without compensatory pelvic motions.

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1. Introduction

Active prone hip extension (PHE) is a strengthening exercise for individuals with some form of weakness in their hip joint muscles (Tateuchi, Taniguchi, Mori, & Ichihashi, 2012). Furthermore, measuring the stability of the lumbopelvic region can be accomplished through PHE (Janda, 1996; Sahrmann, 2002). In addition, previous studies have stated that PHE can be used to evaluate lumbo-pelvic-hip joint muscle activation (Ebrall, 2004; Greenman, 2003; Hertling and Kessler, 2006; Janda, 1996). Sahrmann (2002) reported that individuals with lumbopelvic instability have limitations in controlling excessive extension and rotation of the lumbar spine and anterior tilt and rotation of the pelvis during PHE. Interestingly, over-activity of the erector spinae and hamstring muscles, along with a decreased activation of the gluteus maximus (GM) muscle, has been explained as being due to a change in the activation pattern in these muscles, which can cause movement dysfunction (Janda, 1996; Sahrmann, 2002).

The PHE exercise is one of the primary conventional interventions in rehabilitation to strengthen the GM (Cappozzo, Felici, Figura, & Gazzani, 1985; Wilson, Ferris, Heckler, Maitland, & Taylor, 2005). Kendall, McCreary, and Provance (2005) recommended PHE incorporating a minimum knee flexion of 90° with resistance against the lower part of the posterior thigh for promoting GM strength. However, a modified test of GM strength is used for individuals possessing low back muscle (*i.e.* extensor) weakness and/or hip flexor tightness. Specifically, individuals lie on a table with their trunk in the prone position and legs hanging over the end of the table (Kendall et al., 2005). For example, Kang, Jeon,

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Kwon, Cynn, and Choi (2013) reported that PHE in 90° flexion and 30° hip abduction can lead to maximal GM and minimal hamstring activity versus the 0° hip abduction position. Yoon, Lee, and An (2015) reported that PHE initiated at hip flexion of 20° contributed to greater GM and lower biceps femoris (BF) muscle activities compared with 0° and 45° hip flexion. In addition, Lewis and Sahrmann (2009) reported that muscle activation and movement patterns can be modified by providing verbal cues during the performance of the modified PHE from 30° of hip flexion to neutral.

Comerford and Mottram (2012) proposed that the prone table hip extension test (PTHE) to co-activate the GM and abdominal muscles, which are used to control the lumbar spine and pelvis. Specifically, this test can be performed while the trunk is supported on the table, with both feet placed firmly on the floor, and with the lumbar spine in a neutral position. However, some modified PHE exercises may cause extension and rotation of the lumbar spine, as well as anterior tilting and rotation of the pelvis in compensation if the lumbopelvic region is not stabilized (Comerford & Mottram, 2012; Sahrmann, 2002). Similarly, incorrect exercises for GM strengthening may lead to increased unwanted adjacent muscle activation. Therefore, exercises that decrease muscle activation of the BF and erector spinae (ES) and that selectively strengthen the GM, may be crucially important. Several previous studies have used a pressure bio-feedback unit (PBU) to minimize the lumbopelvic compensation movement using the 'abdominal drawing in maneuver' (ADIM) during lower-extremity exercises (Chance-Larsen, Littlewood, & Garth, 2010; Oh, Weon, Cynn, & Kwon, 2006). However, no literature has compared GM, BF, semitendinosus (ST), and ES activities and compensatory lumbopelvic motion during the three different PHE exercises in healthy participants.

Therefore, the purpose of this study was to compare the muscle amplitudes of the lumbo-pelvic-hip complex, including the ES, GM, BF, and ST muscles and lumbopelvic motions, during performance of three different PHE exercises: the 'conventional' PHE, PTHE, and PTHE with knee flexion (PTHEK). We hypothesize that the muscle activity of GM would be significantly greater in PTHEK compared with conventional PHE and PTHE. Furthermore, by comparing these different PHE exercises, we suggest that GM muscles can be progressively strengthened in advanced rehabilitation programs in both open and closed chain positions.

2. Methods

2.1. Participants

The G*power software was used to estimate sample size (ver. 3.1.2; Franz Faul, University of Kiel, Kiel, Germany) in a pilot study of five participants. A priori calculation of sample size was carried out with a power of 0.80, an alpha level of 0.05, and effect size of 1.58. This result indicated that the necessary sample size was at least six participants for the study. Sixteen healthy male participants (mean ± SD; age = 23.4 ± 2.2 years; body mass = 69.1 ± 7.1 kg; height = 176.7 ± 3.8 cm) were recruited. Exclusion criteria were: 1) iliopsoas or rectus femoris tightness, as evidenced by the modified Thomas test (Kendall et al., 2005); 2) a history of LBP or lower extremity dysfunction, such as patellofemoral pain syndrome, anterior cruciate ligament sprains, or chronic ankle instability in the past 12 months; 3) pain in any region of the body while testing; and 4) limitations in the range of motion of the ipsilateral hip, knee, or ankle joint.

The experimental protocols were explained in detail to all participants, who provided written informed consent. This study was approved by the Yonsei University Wonju Institutional Review Board.

2.2. Electromyography recording and data analysis

Surface electromyography (EMG) feedback was provided by a wireless telemetry system (TeleMyo 2400T, Noraxon, Scottsdale, AZ, USA), and MyoResearch Master Edition 1.06 XP (Noraxon, Scottsdale, AZ, USA) was used to analyze the EMG signals. The EMG signals were amplified using a 1000 gain factor, analog to digital converted and saved with 12 bit resolution and 1000 Hz/channel. A digital band-pass filter (Lancosh FIR, 20–450 Hz) was used to remove movement artifacts, and a notch filter was present to reject any values above 60 Hz. The sampling rate was set at 1024 Hz. The EMG signals were processed as root-mean-square (RMS) data with a moving window of 50 ms. While participants maintained the dominant leg at the target bar during the exercises, EMG signals were recorded for 5 s. EMG signals from 2 to 4 s were used for the analysis. The middle 3 s during the isometric phase of each exercise was used to prevent possible confounding effects due to the start and stop of the exercise (Ayotte, Stetts, Keenan, & Greenway, 2007; Soderberg & Knutson, 2000). To minimize skin resistance, the skin over the gluteal muscle was prepared by cleansing with isopropyl alcohol before electrode placement; then, disposable Ag/AgCl surface electrodes were fixed on the appropriate sites (Cram, Kasman, & Holtz, 1998; Hermens, Freriks, Disselhorst-Klug, & Rau, 2000). Furthermore, electrodes were positioned over the midsection of the gluteal muscle bellies, as detailed in previous studies determining the sites of gluteal muscles (SENIAM, 2016). Specifically, electrodes were placed parallel to the target muscle fiber and placed ~20 mm apart in the direction of the muscle fibers. More specifically, electrodes were placed bilaterally on the lumbar erector spinae (ES: at a two-finger-width distance lateral from the spinous process of L1), dominant gluteus maximus (GM: 50% on the line extending between the sacrum and greater trochanter), semitendinosus (ST: 50% on the line extending between the ischial tuberosity and medial epicondyle), and biceps femoris (BF: 70% on the line extending between the ischial tuberosity and lateral epicondyle) muscles (Marshall and Murphy, 2003). GM, BF and ST electrode placement was on the right leg, which for the purposes of the study was classified as the dominant limb.

2.2.1. Normalization

The manual muscle testing positions for normalization using a maximum voluntary isometric contraction (MVIC) of ES, GM, ST, and BF were trained according to the guidelines of Kendall et al. (2005). The first and last second of the EMG signals of the MVIC tasks were discarded, and the 3 s of remaining data were used for analysis. The mean value of the three MVIC trials was calculated and all EMG signals were expressed as percentages of the MVIC (% MVIC).

2.3. Kinematics measurements

The Polhemus Liberty, an electromagnetic tracking device, was used to calculate pelvic rotation and anterior tilting at 120 Hz (accuracy 0.08 cm for position and 0.15° for orientation) (Mills, Morrison, Lloyd, & Barrett, 2007) and to monitor compensation in pelvic movement (anterior tilting in the sagittal plane and rotation in the transverse plane) during the exercises. No interference was detected with metal objects. The electromagnetic motion sensor was attached to the skin of the sacral spine (S2) by the researcher. The sensor and wire were firmly secured to the same region with adhesive tape to diminish sensor motion artifacts. The transmitter of the electromagnetic tracker system was placed on the right side of the table. During all types of PHE performed, the transmitter was maintained so that its position and orientation remained the same during all measurements.

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