J. Phys. Ther. Sci.
27: 289–291, 2015

Original Article

Effect of abduction and external rotation of the hip joint on muscle onset time during prone hip extension with knee flexion

Tadanobu Suehiro, RPT, MS[1, 2)*], Masatoshi Mizutani, PhD[1)], Hiroshi Ishida, RPT, PhD[2)], Kenichi Kobara, RPT, PhD[2)], Daisuke Fujita, RPT, PhD[2)], Hiroshi Osaka, RPT, PhD[2)], Hisashi Takahashi, RPT, PhD[2)], Susumu Watanabe, RPT, PhD[2)]

[1)] *Graduate School of Health Sciences, Kibi International University, Japan*
[2)] *Department of Rehabilitation, Faculty of Health Science and Technology, Kawasaki University of Medical Welfare: 288 Matsushima, Kurashiki, Okayama 701-0193, Japan*

Abstract. [Purpose] This study investigated the effect of hip position on muscle onset time during prone hip extension with knee flexion. [Subjects] The study included 21 healthy male volunteers. [Methods] Muscle onset times of the right gluteus maximus, right hamstrings, bilateral lumbar erector spinae, and bilateral lumbar multifidus were measured using surface electromyography during right hip extension with knee flexion in the prone position. Measurements were made with the hip in 3 positions: (1) neutral, (2) abduction, and (3) abduction and external rotation. [Results] Gluteus maximus onset relative to the hamstrings was significantly earlier with hip abduction and with hip abduction and external rotation compared with that with the hip in the neutral position. Gluteus maximus onset relative to the hamstrings was significantly earlier with hip abduction and external rotation compared with that with hip abduction. The bilateral multifidus and left lumbar erector spinae onset times relative to the hamstrings were significantly earlier with hip abduction and external rotation compared with those with hip abduction and with the hip in the neutral position. [Conclusion] Abduction and external rotation of the hip during prone hip extension with knee flexion is effective for advancing the onset times of the gluteus maximus, bilateral multifidus, and contralateral lumbar erector spinae.

Key words: Prone hip extension with knee flexion, Hip joint position, Muscle onset time

(This article was submitted Jul. 7, 2014, and was accepted Aug. 24, 2014)

INTRODUCTION

Both local (deep, intersegmental) and global (large, superficial) muscles contribute to the maintenance of lumbopelvic stability[1, 2)], whereas global muscles are primarily involved in movement and control of the spine. Specifically, global muscles act to control spinal orientation, balance external loads applied to the trunk, and transfer loads directly from the spine to the leg during movement[3, 4)]. Since the gluteus maximus (GM) is aligned perpendicular to the sacroiliac joint, GM activity compresses the sacroiliac joint and contributes to pelvic stability[5)]. Patients with low back pain have been reported to demonstrate delayed GM activity during prone hip extension movement compared with healthy subjects[6)]. Patients with sacroiliac joint pain also have been reported to show delayed GM activity and early hamstring activity in the supporting leg when the contralateral hip is flexed[7)]. Inappropriate timing of GM activation during gait is believed to be one cause of low back pain and to result from a deficient shock absorption mechanism in the sacroiliac joint[8)]. From these observations, improving the activation pattern of the GM is important for the prevention and treatment of pain in the sacroiliac joint and low back[9)].

Several studies have demonstrated methods to reduce delayed firing of the GM. Sakamoto et al.[10)] found that prone hip extension with knee flexion (PHEKF) or prone hip extension with hip external rotation leads to an earlier GM onset time compared with prone hip extension alone. Furthermore, Kang et al.[11)] investigated the difference in electromyographic (EMG) onset time of the GM relative to the hamstrings during PHEKF exercise with hip abduction and with the hip in neutral, and also recommended that PHEKF with hip abduction is effective for speeding up the onset time of the GM.

The impact of compound movement involving hip abduction and external rotation on muscle onset time during PHEKF exercise has not been investigated. Therefore, this study investigated the GM onset time during PHEKF with different hip joint positions. Furthermore, since Silfies et al.[12)] reported delayed back muscle onset times in patients with low back pain, we also investigated the onset time of certain back muscles.

*Corresponding author. Tadanobu Suehiro (E-mail: suehiro@mw.kawasaki-m.ac.jp)

SUBJECTS AND METHODS

Ethical approval to perform this study was granted by the Ethics Committee of Kawasaki University of Medical Welfare, and all subjects provided written informed consent prior to participation. Twenty-one healthy male participants were recruited. Their mean age was 20.2 ± 0.4 years, mean weight was 64.3 ± 10.5 kg, and mean height was 171.1 ± 5.0 cm. The exclusion criteria were history of neuromuscular or musculoskeletal disorder and absence of a normal range of movement.

EMG signals were recorded using a surface EMG system (Vital Recorder 2; Kissei Comtec, Nagano, Japan) with a 1,000-Hz sampling frequency. Disposable electrodes (Blue Sensor M-00-S; Ambu, Ballerup, Denmark) were placed on the right GM (halfway between the greater trochanter and the second sacral vertebra), right hamstrings (approximately halfway between the gluteal fold and the popliteal fold[11]), bilateral lumbar erector spinae (LES) (2–3 cm lateral to the L1 spinous process), and bilateral lumbar multifidus (LM) (immediately lateral to the L5 spinous process). The interelectrode gaps were set to 2.5 cm, and the reference electrode was attached to the second sacral vertebra.

Measurements were made with the hip joint in 3 positions: (1) neutral (N), (2) abduction (AB), and (3) abduction and external rotation (ABER). Each participant was positioned prone with his arms down at his sides and with 90° of right knee flexion. In position N, the right hip joint had 0° of abduction and 0° of external rotation. In position AB, the joint had 15° of abduction and 0° of external rotation. In position ABER, the joint had 15° of abduction and 20° of external rotation. Measurements of the hip joint angle were conducted using a goniometer (OG Giken, Okayama, Japan). Abduction was determined by the angle formed by the center line of the thigh and a line perpendicular to a line connecting both posterior superior iliac spines. External rotation was determined by the angle formed by the center line of the lower leg and a plumb line passing through the patella. Bars were installed vertically inside and outside of the right thigh to avoid changing the abduction angle during the measurements. The right leg of the subject was relaxed and held in the starting position by a tester. A light-emitting diode (LED) lamp was placed in front of the subject. Each subject was instructed to extend his right hip joint at a natural speed[10] while actively maintaining knee flexion, hip abduction, and hip external rotation angles when the LED lamp was lit. Before data acquisition, all subjects practiced the PHEKF exercise for 5 min to familiarize themselves with the testing procedure. The subjects performed the PHEKF exercise 3 times for each hip position and were allowed a 2-min rest period between each measurement. The order of measurements for the 3 positions (N, AB, and ABER) was randomly assigned. All EMG waveforms were processed through a band-pass filter (20–500 Hz), and full-wave rectification was subsequently performed. Baseline EMG data were calculated by averaging the EMG activity for a 5-s interval in a resting position. The onset of EMG activity was considered to occur when the value exceeded 2 SDs from the mean value observed at baseline[10, 11, 13]. The relative onset difference between each muscle and the hamstrings was calculated by the following equation[11, 14, 15]: relative onset difference = each muscle onset − hamstrings onset (in ms). Therefore, a negative value indicated that the target muscle fired before the hamstrings and vice versa. To reduce the variability for each measured muscle, we averaged 3 measurements for each position as a representative value.

Table 1. Relative onset difference between each muscle and the hamstrings (ms)

	Position N	Position AB	Position ABER
Right GM	108.4 ± 142.1	−32.4 ± 130.3[a]	−109.1 ± 173.7[ab]
Right LM	−71.1 ± 102.1	−105.7 ± 128.5	−188.7 ± 203.0[ab]
Right LES	23.2 ± 136.2	−12.5 ± 170.5	−38.9 ± 234.6
Left LM	−19.1 ± 104.0	−25.0 ± 157.0	−98.3 ± 204.1[ab]
Left LES	4.5 ± 112.1	26.8 ± 172.0	−75.8 ± 207.3[ab]

All values are expressed as means ± SD. A negative value indicates that the target muscle fired before the hamstrings. A positive value indicates that the target muscle fired after the hamstrings. [a]Significantly different compared with position N ($p < 0.05$).[b]Significantly different compared with position AB ($p < 0.05$). GM: gluteus maximus, LES: lumbar erector spinae, LM: lumbar multifidus

SPSS version 21 for Windows (IBM Corporation, Armonk, NY, USA) was used for all statistical analyses. Repeated measures analysis of variance and multiple comparisons (Bonferroni test) were used to detect differences in relative muscle onset time among the 3 positions (N, AB, and ABER). The level of significance was set at $p < 0.05$.

RESULTS

The relative onset difference between each muscle and the hamstrings is shown in Table 1. GM onset relative to the hamstrings was significantly earlier in positions AB and ABER compared with position N. GM onset relative to the hamstrings was significantly earlier in position ABER compared with position AB. Bilateral LM and left LES onset relative to the hamstrings was significantly earlier in position ABER compared with positions N and AB.

DISCUSSION

In patients with low back and sacroiliac joint pain, delayed GM activity and early hamstrings activity have been noted[6, 7]. These muscle activity patterns cause sacroiliac instability and increase strain on the soft tissue[8]. In this study, we investigated whether the hip joint position affects GM onset relative to the hamstrings during PHEKF exercise.

We observed that GM onset relative to the hamstrings was significantly earlier in positions AB and ABER compared with position N. This result is consistent with the report by Kang et al.[11], who studied the effects of hip joint abduction during PHEKF exercise. We can explain this change in GM onset by the function of the GM; the GM as a whole acts as a powerful extensor and external rotator of the hip, while the upper fibers of the GM act as an abductor of the hip[16]. In this study, subjects abducted the hip prior to and during performance of PHEKF exercise, which led to GM activation as a hip abductor, and this increased its responsiveness during PHEKF relative to position N. GM onset relative to the hamstrings was also significantly earlier in the ABER position than in the AB position. Previous work demonstrated that because external rotation of the hip in PHEKF exercise reduces the amount of hamstring muscle activity and the hip extension moment that can be exerted by the hamstrings, the GM is more active as an extensor compared with the hamstrings[17]. Therefore, the relative onset time of the GM as a driving force for hip extension in position ABER seems to have occurred earlier.

Bilateral LM and left LES onset relative to the hamstrings was significantly earlier in position ABER compared with positions N and AB. The iliofemoral and pubofemoral ligaments are tense in position ABER, resulting in decreased range of hip joint extension and increased anterior pelvic tilt moment. Reduced onset latency of the contralateral and ipsilateral LM and contralateral LES has been reported to be related to decreased anterior pelvic tilt during prone hip extension[18]. In addition, Wilke et al.[19] demonstrated that simulation of the force of the entire LM group reduced the range of motion of the lumbar spine not only in flexion and rotation but also in extension. In light of these reports, it is thought that the bilateral LM and left LES were activated early in position ABER in the present study in order to prevent lumbar spine extension and anterior pelvic tilt.

We observed that the GM, bilateral LM, and left LES onset times relative to the hamstrings were significantly earlier in position ABER compared with positions N and AB. Delayed onset of GM, LM, and LES activation, which occurs in patients with low back pain, has been reported to diminish the effectiveness of lumbopelvic stabilizing mechanisms[7, 12]. Furthermore, Tateuchi et al.[18] reported that when the LM and contralateral LES onset times are delayed during prone hip extension, the degree of anterior pelvic tilt increases. These excessive lumbopelvic movements can lead to compression and extension stress on the vertebrae and surrounding soft tissue, causing low back pain[4, 20]. These facts imply that PHEKF exercise with hip abduction and external rotation for early activation of the GM, LM, and LES is likely to be beneficial in the prevention and treatment of low back pain. However, this study was cross-sectional, and all subjects who participated were healthy young men. Therefore, a future intervention study of PHEKF exercise with hip abduction and external rotation in patients with low back pain should confirm whether delayed muscle onset during hip extension can be improved and whether low back pain can be reduced.

The limitation of this study is that the speed of the movements was not controlled. It is well known that the magnitude of the EMG signal can be directly influenced by several factors, such as speed, acceleration, range of movement, load, and number of repetitions. However, although the speed was not controlled, subjects were instructed to perform hip extension at their natural speed in order to reproduce a situation similar to that employed in clinical practice.

REFERENCES

1) Bergmark A: Stability of the lumbar spine. A study in mechanical engineering. Acta Orthop Scand Suppl, 1989, 230: 1–54. [Medline] [CrossRef]
2) Kim JW, Han JY, Kang MH, et al.: Comparison of posterior oblique sling activity during hip extension in the prone position on the floor and on a round foam roll. J Phys Ther Sci, 2013, 25: 977–979. [Medline] [CrossRef]
3) Danneels LA, Vanderstraeten GG, Cambier DC, et al.: A functional subdivision of hip, abdominal, and back muscles during asymmetric lifting. Spine, 2001, 26: E114–E121. [Medline] [CrossRef]
4) Richardson CA, Hodges PW, Hides JA: Therapeutic exercise for lumbopelvic stabilization: a motor control approach for the treatment and prevention of low back pain. 2nd ed, Edinburgh: Churchill Livingstone, 2004, pp 16–19.
5) Vleeming A, Snijders C, Stoeckart R, et al.: The role of the sacroiliac joints in coupling between spine, pelvis, legs and arms. In: Movement, Stability and Low Back Pain. New York: Churchill-Livingstone, 1997, pp 53–71.
6) Bruno PA, Bagust J: An investigation into motor pattern differences used during prone hip extension between subjects with and without low back pain. Clin Chiropract, 2007, 10: 68–80. [CrossRef]
7) Hungerford B, Gilleard W, Hodges P: Evidence of altered lumbopelvic muscle recruitment in the presence of sacroiliac joint pain. Spine, 2003, 28: 1593–1600. [Medline] [CrossRef]
8) Hossain M, Nokes LD: A model of dynamic sacro-iliac joint instability from malrecruitment of gluteus maximus and biceps femoris muscles resulting in low back pain. Med Hypotheses, 2005, 65: 278–281. [Medline] [CrossRef]
9) Jung HS, Jeon HS, Oh DW, et al.: Effect of the pelvic compression belt on the hip extensor activation patterns of sacroiliac joint pain patients during one-leg standing: a pilot study. Man Ther, 2013, 18: 143–148. [Medline] [CrossRef]
10) Sakamoto AC, Teixeira-Salmela LF, de Paula-Goulart FR, et al.: Muscular activation patterns during active prone hip extension exercises. J Electromyogr Kinesiol, 2009, 19: 105–112. [Medline] [CrossRef]
11) Kang SY, Jeon HS, Kwon O, et al.: Activation of the gluteus maximus and hamstring muscles during prone hip extension with knee flexion in three hip abduction positions. Man Ther, 2013, 18: 303–307. [Medline] [CrossRef]
12) Silfies SP, Mehta R, Smith SS, et al.: Differences in feedforward trunk muscle activity in subgroups of patients with mechanical low back pain. Arch Phys Med Rehabil, 2009, 90: 1159–1169. [Medline] [CrossRef]
13) Hodges PW, Bui BH: A comparison of computer-based methods for the determination of onset of muscle contraction using electromyography. Electroencephalogr Clin Neurophysiol, 1996, 101: 511–519. [Medline]
14) Chance-Larsen K, Littlewood C, Garth A: Prone hip extension with lower abdominal hollowing improves the relative timing of gluteus maximus activation in relation to biceps femoris. Man Ther, 2010, 15: 61–65. [Medline] [CrossRef]
15) Tateuchi H, Tsukagoshi R, Fukumoto Y, et al.: Pelvic instability and trunk and hip muscle recruitment patterns in patients with total hip arthroplasty. J Electromyogr Kinesiol, 2013, 23: 151–158. [Medline] [CrossRef]
16) Netter FH: The CIBA collection of medical illustrations: Musculoskeletal system. Anatomy, physiology and metabolic disorders. New York: CIBA-GEIGY Corporation, 1987.
17) Suehiro T, Mizutani M, Okamoto M, et al.: Influence of hip joint position on muscle activity during prone hip extension with knee flexion. J Phys Ther Sci, 2014 (in press).
18) Tateuchi H, Taniguchi M, Mori N, et al.: Balance of hip and trunk muscle activity is associated with increased anterior pelvic tilt during prone hip extension. J Electromyogr Kinesiol, 2012, 22: 391–397. [Medline] [CrossRef]
19) Wilke HJ, Wolf S, Claes LE, et al.: Stability increase of the lumbar spine with different muscle groups. A biomechanical in vitro study. Spine, 1995, 20: 192–198. [Medline] [CrossRef]
20) Gardner-Morse M, Stokes IA, Laible JP: Role of muscles in lumbar spine stability in maximum extension efforts. J Orthop Res, 1995, 13: 802–808. [Medline] [CrossRef]