J. Phys. Ther. Sci.
27: 893–895, 2015

Original Article

Activation of the vastus medialis oblique and vastus lateralis muscles in asymptomatic subjects during the sit-to-stand procedure

Boram Choi[1)]

[1)] *Department of Physical Therapy, College of Medical and Life Sciences, Silla University: 140 Baegyang-daero, 700beon-gil, Sasang-gu, Busan, Republic of Korea*

Abstract. [Purpose] The purpose of this study was to examine the vastus medialis oblique to vastus lateralis ratio in two pelvic tilt positions while performing the sit-to-stand task. [Subjects and Methods] Activation of the vastus medialis oblique and the vastus lateralis muscles of 46 healthy subjects (25 males, 21 females) were recorded by surface electromyography during the STS task with anterior pelvic tilt (sit with thoracolumbar spine extended and pelvis in an anterior tilt) and neutral pelvic tilt (sit with thoracolumbar spine relaxed and pelvis in the neutral tilt position) positions. Changes in vastus medialis oblique, vastus lateralis activation and the vastus medialis oblique/vastus lateralis ratio were analyzed. [Results] Vastus medialis oblique and vastus lateralis muscle activation significantly increased in neutral pelvic tilt position, but the vastus medialis oblique/vastus lateralis ratio was not statistically different. [Conclusion] The sit-to-stand procedure with neutral pelvic tilt position increased activation of the vastus medialis oblique and vastus lateralis, usefully strengthening the quadriceps, but did not selectively activate the vastus medialis oblique muscle.
Key words: Anterior pelvic tilt, Neutral pelvic tilt, Sit-to-stand task

(This article was submitted Sep. 29, 2014, and was accepted Nov. 7, 2014)

INTRODUCTION

Patellofemoral pain syndrome (PFPS) is a common disorder of the knee joint, and occurs in both athletes and the general population[1, 2)]. PFPS is difficult to diagnose, is multifactorial, and includes lower extremity malalignment (increased Q angle, patella alta, external rotation of the tibia, and pronated foot), muscle weakness (hip abductors and external rotators), and muscle imbalance (vastus medialis oblique [VMO] muscle versus vastus lateralis [VL] muscle and tensor fascia latae)[3, 4)]. Previous research has focused on treatment of the knee joint, such as conservative treatment (taping, bracing, modality), and knee joint muscle exercises (VMO muscle strengthening, altered VMO muscle onset time)[5, 6)]. Although conservative treatment and knee joint muscle exercises reduce pain and dysfunction, some PFPS patients consistently report unequal effectiveness and knee joint dysfunction with proximal treatment (lumbo-pelvic region exercise, hip abductor, and external rotator strengthening)[7, 8)]. Because hip abductor and external rotator weakness induces knee valgus and increased patellar lateral tracking, proximal joint muscle exercises can correct lower extremity alignment[9, 10)].

Knee joint alignment is influenced by the proximal structures located above the knee. For example, excessive anterior pelvic tilt produces increased femoral anteversion (FA) due to the increased acetabular anteversion angle, and the femoral head is less covered than in the normal hip joint position. Increased FA results in greater internal rotation of the femur, displacing the patella laterally relative to the ASIS and tibial tuberosity line, increasing the Q-angle and the valgus knee alignment[11)]. Knee valgus increases the risk of lateral knee OA progression and PFPS, because the load-bearing axis passes lateral to the centerline of the knee, and the resulting moment arm increases the bowstringing force across the lateral compartment[12, 13)]. Therefore, PFPS treatment needs to correct the proximal joint for the normal alignment of the knee joint.

The sit-to-stand (STS) procedure is one of the most frequently used exercises for examining the changes in the VMO and VL muscle activities, and the onset time in PFPS patients or healthy subjects[14, 15)]. Nevertheless, there is a lack of scientific data relating to the required pelvic tilt position for the STS task. Normal STS requires coordinated spatiotemporal interaction between linked body segments. Between the onset of STS and buttocks lift-off, forward leaning is accomplished by concurrent trunk and hip flexion, and anterior pelvic tilt[16, 17)]. Therefore, there is a need to recognize the differences in the activation of the VMO and VL muscles according to the proximal pelvic tilt position during STS. The purpose of this study was to examine the VMO to VL ratio in two pelvic tilt positions while performing the STS task.

Corresponding author. Boram Choi (E-mail: boram@silla.ac.kr)

SUBJECTS AND METHODS

We conducted an a priori sample-size power analysis using the variability of the VMO:VL ratio obtained from pilot data. Based on this analysis, 25 participants in the male group (two tails, β=0.20, α=0.05, effect size=0.57) and 21 participants in the female group (two tails, β=0.20, α=0.05, effect size=1.15) were required to adequately power this study. The participants were 25 men (age=24.3 ± 3.9 years, height=1.73 ± 0.03 m, weight=69.8 ± 8.7 kg) and 21 women (age=20.9 ± 0.9 years, height=1.60 ± 0.03 m, weight=54.4 ± 4.3 kg). The inclusion criteria were no history of orthopedic surgery, a lower limb length difference of no more than 1 cm, and no pain during the STS task[18]. Before taking part, the participants provided their written informed consent. This study was approved by the Institutional Review Board of Silla University.

Activation of the quadriceps femoris muscle was recorded using a Noraxon Telemyo 2400T DTS Telemetry system (Noraxon, Inc., Scottsdale, AZ, USA). Three bipolar Ag–AgCl surface electrodes (Blue Sensor, Olystyke, Denmark) with a diameter of 1.8 cm and an interelectrode distance of 2 cm were placed on the rectus femoris, the vastus medialis and the vastus lateralis. The vastus medialis (VMO) electrode was placed on the center of the muscle belly, approximately 4 cm superior and 3 cm medial to the superomedial patella border, and was orientated at 55° to the virtual line of orientation of the muscle fiber. The vastus lateralis (VL) electrode was placed 10 cm superior and 7 cm lateral to the superior border of the patella, and was orientated 15° to the virtual line of orientation of the muscle fiber. The single reference was an electrode placed on the patellar center[5]. All of the EMG electrodes were placed by the same examiner.

EMG data were processed using the MyoResearch Master Edition 1.08 XP software (Noraxon, Inc., Scottsdale, AZ, USA). Raw EMG data were recorded after band-pass filtering between 20 and 450 Hz, and were sampled at 3,000 Hz using a 12-bit analog–digital conversion. The root mean square (RMS) was smoothed with a moving window of 50 ms. For maximum voluntary isometric contraction (MVIC) of the VMO and VL muscles, the participants sat on a backless chair with 90° hip flexion and full knee extension. They performed 5 s isometric contractions of their quadriceps femoris muscle[19].

The participants performed the STS with anterior pelvic tilt (APT) and neutral pelvic tilt (NPT) sitting postures. For the APT position in the sitting posture, the participants were instructed to sit with their thoracolumbar spine extended and their pelvis in an anterior tilt. The participants stood up naturally. For the NPT position in the sitting posture, the participants were instructed to sit with their thoracolumbar spine relaxed and their pelvis in the neutral tilt position[20]. They were also instructed to maintain their pelvis in the neutral position by abdominal muscle contraction until completion of the STS. Prior to the STS trials, the participants were allowed to familiarize themselves with the procedure. Each participant performed five STS trial procedures for each sitting posture at a self-selected speed. Participants sat on an armless, backless, and height-adjustable chair in their bare feet with their arms folded across the chest. Each foot was placed on the ground, maintaining the same foot position (between ASIS length) in each trial. The knee joint was flexed at 90° so the second toe was vertically below the knee. Participants were asked to look at a fixed point (2 m above the ground and 4 m ahead of the chair)[21].

Table 1. Normalized VMO and VL activation, and the VMO/VL ratio during STS in the APT and NPT positions

		APT	NPT
Male	VMO	59.6 (± 35.2)	79.5 (± 61.6)*
	VL	54.2 (± 27.9)	71.4 (± 43.7)*
	VMO/VL ratio	1.1 (± 0.4)	1.0 (± 0.3)
Female	VMO	49.5 (± 33.9)	61.5 (± 42.3)*
	VL	47.7 (± 29.3)	60.7 (± 36.1)*
	VMO/VL ratio	1.0 (± 0.3)	1.0 (± 0.2)

APT: anterior pelvic tilt, NPT: neutral pelvic tilt, VMO: vastus medialis oblique, VL: vastus lateralis
*$p<0.05$

The independent variables were the APT and the NPT positions. The dependent variables were activation of the VMO and VL muscles, and the VMO:VL ratio. A two-tailed, paired t-test was performed to compare the muscle activations and their ratio between APT and NPT using SPSS statistical software (ver. 18.0; Norusis/SPSS Inc., Chicago, IL, USA). The alpha level was chosen a priori as 0.05.

RESULTS

Table 1 shows the change in activation of the VMO and the VL, and the change in the VMO:VL ratio of the men and women in the APT and NPT positions during STS. VMO and VL activation increased significantly more in NPT than APT, but the VMO:VL ratio was not significantly different between the two task.

DISCUSSION

The VL and VMO muscles showed significantly increased activation in the NPT position compared to the APT position. Previous studies have focused on effortless methods to improve the performance of the STS. Increasing the seat height relative to knee height decreased the lower limb joint and the muscle force[22], and increasing the seat cushion thickness caused difficulties for older subjects performing the STS procedure[23]. However, in this study, we assessed the NPT position for more effective quadriceps femoris muscle strengthening during the STS exercises. In the study of muscle function and coordination during movement, the vastus muscle has a relatively large extension moment compared to other knee extensors during knee extension[24]. STS with the NPT position produced minimal hip flexion and maximal knee extension. Generally, STS elicits an anterior pelvic tilt. An anterior pelvic tilt is caused by the hip flexor and back extensor muscles acting as a ‘force couple’ for lumbar lordosis. However, repetitive increased activation of the erector spinae (ES) and RF may induce lumbar lordosis and low-back pain[25]. In this study, instead of ES muscle contraction, abdominal muscle contraction was performed to maintain the NPT position to decrease lower spine stress. The NPT position showed significant knee extension activation compared to the APT position. Thus, STS exercise in the NPT position can improve the function of the knee extension without lumbar spine stress.

Generally, patellofemoral rehabilitation programs are conducted to maximize quadriceps femoris muscle strength while minimizing patellofemoral joint reaction forces and stress[3]. Exercises to strengthen the quadriceps femoris muscle are conducted using many methods. Traditionally, quad sets and knee-extension exercises have commonly been used. STS exercises are also used to strengthen the quadriceps femoris muscle[26]. At the time of transfer from the chair, the body is often in an unstable position, with the center of mass located posterior to the heel and outside the base of support[27]. Thus, the quadriceps femoris muscle must be activated to maintain knee stability and stimulate muscle activation during STS[28].

The rational evidence for hip extensor and external rotator strengthening for treatment of PFPS is that internal rotation of the hip causes knee valgus deformity, patellar lateral shifting, and anterior knee pain[9]. In this study, the NPT position during STS limited hip movement giving proximal joint stability. However, the VMO/VL ratio did not improve during STS with the NPT position. Previous studies have reported that proximal strengthening improves the functional score and hip joint muscle flexibility, and lessens the pain of the PFPS patients[28]. Although the proximal strengthening protocol does not focus on the muscles of the surrounding knee joint, it decreases dysfunction and pain in the knee joint. Therefore, proximal strengthening for PFPS treatment does not affect the VMO:VL ratio, but does correct the knee joint alignment.

This study demonstrated the effect of the pelvic tilt position on activation of the VMO and VL muscles during performance of the STS task. NPT increased the activation of the VMO and VL muscles. However, the VMO:VL ratio showed no significant between the APT and NPT position. This finding implies that the NPT position during STS only benefits quadriceps strengthening.

REFERENCES

1) Lichota DK: Anterior knee pain: symptom or syndrome? Curr Womens Health Rep, 2003, 3: 81–86. [Medline]
2) Dixit S, DiFiori JP, Burton M, et al.: Management of patellofemoral pain syndrome. Am Fam Physician, 2007, 75: 194–202. [Medline]
3) Tang SF, Chen CK, Hsu R, et al.: Vastus medialis obliquus and vastus lateralis activity in open and closed kinetic chain exercises in patients with patellofemoral pain syndrome: an electromyographic study. Arch Phys Med Rehabil, 2001, 82: 1441–1445. [Medline] [CrossRef]
4) Papadopoulos K, Noyes J, Jones JG, et al.: Clinical tests for differentiating between patients with and without patellofemoral pain syndrome. Hong Kong Physiotherapy J, 2014, 32: 35–43. [CrossRef]
5) Cowan SM, Bennell KL, Crossley KM, et al.: Physical therapy alters recruitment of the vasti in patellofemoral pain syndrome. Med Sci Sports Exerc, 2002, 34: 1879–1885. [Medline] [CrossRef]
6) Coqueiro KR, Bevilaqua-Grossi D, Bérzin F, et al.: Analysis on the activation of the VMO and VLL muscles during semisquat exercises with and without hip adduction in individuals with patellofemoral pain syndrome. J Electromyogr Kinesiol, 2005, 15: 596–603. [Medline] [CrossRef]
7) Peters JS, Tyson NL: Proximal exercises are effective in treating patellofemoral pain syndrome: a systematic review. Int J Sports Phys Ther, 2013, 8: 689–700. [Medline]
8) Collins NJ, Bisset LM, Crossley KM, et al.: Efficacy of nonsurgical interventions for anterior knee pain: systematic review and meta-analysis of randomized trials. Sports Med, 2012, 42: 31–49. [Medline] [CrossRef]
9) Powers CM: The influence of altered lower-extremity kinematics on patellofemoral joint dysfunction: a theoretical perspective. J Orthop Sports Phys Ther, 2003, 33: 639–646. [Medline] [CrossRef]
10) Willson JD, Davis IS: Utility of the frontal plane projection angle in females with patellofemoral pain. J Orthop Sports Phys Ther, 2008, 38: 606–615. [Medline] [CrossRef]
11) Neumann DA: Kinesiology of the musculoskeletal system; Foundation for rehabilitation. Mosby, 2010.
12) Tetsworth K, Paley D: Malalignment and degenerative arthropathy. Orthop Clin North Am, 1994, 25: 367–377. [Medline]
13) Sharma L, Song J, Felson DT, et al.: The role of knee alignment in disease progression and functional decline in knee osteoarthritis. JAMA, 2001, 286: 188–195. [Medline] [CrossRef]
14) Ng GY, Zhang AQ, Li CK: Biofeedback exercise improved the EMG activity ratio of the medial and lateral vasti muscles in subjects with patellofemoral pain syndrome. J Electromyogr Kinesiol, 2008, 18: 128–133. [Medline] [CrossRef]
15) Wong YM, Ng G: Resistance training alters the sensorimotor control of vasti muscles. J Electromyogr Kinesiol, 2010, 20: 180–184. [Medline] [CrossRef]
16) Sibella F, Galli M, Romei M, et al.: Biomechanical analysis of sit-to-stand movement in normal and obese subjects. Clin Biomech (Bristol, Avon), 2003, 18: 745–750. [Medline] [CrossRef]
17) Tully EA, Fotoohabadi MR, Galea MP: Sagittal spine and lower limb movement during sit-to-stand in healthy young subjects. Gait Posture, 2005, 22: 338–345. [Medline] [CrossRef]
18) Pinto RZ, Souza TR, Trede RG, et al.: Bilateral and unilateral increases in calcaneal eversion affect pelvic alignment in standing position. Man Ther, 2008, 13: 513–519. [Medline] [CrossRef]
19) Palmieri-Smith RM, McLean SG, Ashton-Miller JA, et al.: Association of quadriceps and hamstrings cocontraction patterns with knee joint loading. J Athl Train, 2009, 44: 256–263. [Medline] [CrossRef]
20) O'Sullivan K, O'Dea P, Dankaerts W, et al.: Neutral lumbar spine sitting posture in pain-free subjects. Man Ther, 2010, 15: 557–561. [Medline] [CrossRef]
21) Rodosky MW, Andriacchi TP, Andersson GB: The influence of chair height on lower limb mechanics during rising. J Orthop Res, 1989, 7: 266–271. [Medline] [CrossRef]
22) Rojhani Shirazi Z, Biabani Moghaddam M, Motealleh A: Comparative evaluation of core muscle recruitment pattern in response to sudden external perturbations in patients with patellofemoral pain syndrome and healthy subjects. Arch Phys Med Rehabil, 2014, 95: 1383–1389. [Medline] [CrossRef]
23) Anan M, Okumura K, Kito N, et al.: Effects of variation in cushion thickness on the sit-to-stand motion of elderly people. J Phys Ther Sci, 2008, 20: 51–57. [CrossRef]
24) Hoy MG, Zajac FE, Gordon ME: A musculoskeletal model of the human lower extremity: the effect of muscle, tendon, and moment arm on the moment-angle relationship of musculotendon actuators at the hip, knee, and ankle. J Biomech, 1990, 23: 157–169. [Medline] [CrossRef]
25) Lee CM, Jeong EH, Freivalds A: Biomechanical effects of wearing high-heeled shoes. Int J Ind Ergon, 2001, 28: 321–326. [CrossRef]
26) Yamashita F, Iwamoto J, Osugi T, et al.: Chair rising exercise is more effective than one-leg standing exercise in improving dynamic body balance: a randomized controlled trial. J Musculoskelet Neuronal Interact, 2012, 12: 74–79. [Medline]
27) Gross MM, Stevenson PJ, Charette SL, et al.: Effect of muscle strength and movement speed on the biomechanics of rising from a chair in healthy elderly and young women. Gait Posture, 1998, 8: 175–185. [Medline] [CrossRef]
28) Esenyel M, Walsh K, Walden JG, et al.: Kinetics of high-heeled gait. J Am Podiatr Med Assoc, 2003, 93: 27–32. [Medline] [CrossRef]