J Int Acad Phys Ther Res 2019; 10(3): 1818~1822
ISSN 2092-8475
www.iaptr.org
https://doi.org/10.20540/JIAPTR.2019.10.3.1818

Change in Pelvic Motion Caused by Visual Biofeedback Influences Trunk and Hip Muscle Activities During Side-Lying Hip Abduction in Asymptomatic Individuals

Background: Ipsilateral pelvic elevation has been reported as a common compensatory movement during side-lying hip abduction. It has been reported that pelvic elevation inhibits sufficient contraction of gluteus medius. However, few studies have identified the effects of controlled pelvic elevation on the trunk and hip muscles.
Objective: To examine the effects of controlled pelvic elevation using visual biofeedback on the muscle activity of the trunk and hip muscles.
Design: Crossover study.
Methods: Twelve healthy males performed side-lying hip abduction exercises with and without visual biofeedback for pelvic elevation. Electromyography (EMG) activities of the gluteus medius, quadratus lumborum, and multifidus were analyzed using a wireless EMG system while the ipsilateral pelvic elevation angle was measured using a motion sensor during side-lying hip abduction exercises.
Results: EMG activities of the gluteus medius ($p = .002$), quadratus lumborum ($p = .022$), and multifidus ($p = .020$) were significantly increased and ipsilateral pelvic elevation was significantly decreased ($p = .001$) during side-lying hip abduction with visual biofeedback compared to without visual biofeedback.
Conclusions: The results of this study suggest that the application of biofeedback for pelvic motion could improve the trunk and hip muscle activation pattern and decrease compensatory pelvic motion during side-lying hip abduction exercise.

Key words: *Biofeedback; Electromyography; Hip abduction*

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Received : 9 August 2019
Revised : 27 August 2019
Accepted : 11 September 2019

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INTRODUCTION

Side-lying hip abduction is a common exercise to strengthen the gluteus medius, an agonist of hip abduction [1-5]. Muscle activity of the gluteus medius is increased during side-lying hip abduction because the force of gravity is applied to the lower extremity as a means of resistance [6]. Previous studies have shown that about 25% of the maximal voluntary isometric contraction (MVIC) of the gluteus medius is activated during side-lying hip abduction without additional resistance [3-4], which indicates that side-lying hip abduction could facilitate gluteus medius activation at a moderate level [5].

Compensatory movements often accompany side-lying hip abduction exercises [3, 4, 7]. The most common compensatory movement during side-lying hip abduction is ipsilateral pelvic elevation [3, 4]. Co-contraction of the quadratus lumborum during side-lying hip abduction leads to combined movements of pelvic elevation and hip abduction, which could interrupt adequate muscle activation of hip abductors such as the gluteus medius [3, 4]. Thus, it is important to restrict ipsilateral pelvic elevation during side-lying hip abduction exercises.

Previous studies have used a pressure biofeedback unit (PBU) to prevent compensatory movements during side-lying hip abduction [2, 4]. An increase in pressure on a PBU placed between the lateral lumbar spine and the table indicates lateral trunk movement caused by ipsilateral pelvic elevation during side-lying hip abduction [4, 8]. However, because the PBU is analog, it is difficult for subjects to intuitively identify changes in pressure. Additionally, because changes in pressure may result from lateral trunk movement, it is difficult to directly measure compensatory ipsilateral pelvic elevation during side-lying hip abduction exercises.

Recent technology permits the real-time measurement of segmental movements by linking to a smartphone with a three-axis accelerometer [9, 10]. However, few studies have verified the effects of this type of real-time motion sensor on controlled pelvic movement exercises. To our knowledge, only one study has examined the effects of controlled pelvic movements on hip muscle activity using an accelerometer for biofeedback [11]. The previous study showed increased gluteus medius muscle activity during side-lying hip abduction when applying biofeedback for pelvic movement [11]. However, it did not verify how using the motion sensor to control pelvic movements influences the trunk stabilizer muscles such as the multifidus during side-lying hip abduction. Given that contraction of the multifidus is an important component of a trunk stabilization program, changes in multifidus muscle activity caused by controlled pelvic movements would provide useful information to clinicians. Thus, the aim of this study was to identify the influence of using a motion sensor for visual biofeedback on trunk and hip muscle activation during side-lying hip abduction exercises.

SUBJECTS AND METHODS

Subjects

In total, 12 healthy male subjects (age = 24.17 ± 0.94 years; height = 172.50 ± 4.38 cm; body weight = 69.33 ± 7.10 kg) who could perform side-lying hip abduction without discomfort or difficulty participated in this study. Exclusion criteria included limitations in hip abduction, history of surgery or injury in the lower extremity within the last year, and pain in the trunk and/or lower extremity in the last 2 weeks. The study protocol was approved by a public institutional review board designated by the Ministry of Health and Welfare (P01-201905-11-002).

Measures of trunk and hip muscle activation

During side-lying hip abduction exercises, electromyography (EMG) of the gluteus medius, quadratus lumborum, and multifidus on the side of hip abduction were recorded using wireless miniDTS sensors (Noraxon, Inc., Scottsdale, AZ, USA). The sampling rate of the EMG was 1500 Hz and the filter bandwidth was 10–450 Hz. Two bipolar surface electrodes were attached for each muscle (gluteus medius: proximal third of distance between iliac crest and greater trochanter, quadratus lumborum: lateral from erector spinae with half distance between 12th rib and iliac crest, multifidus: 2 cm lateral from L5 spinous process) [3, 12]. To normalize the EMG data, MVICs for each muscle were measured using the methods suggested by Hislop et al. [13] Each MVIC trial was performed for 5 s, but only the middle 3 s was used for calculations [1]. The trials were repeated twice for each muscle and the mean value of the two trials was used to calculate the final MVIC of each muscle. During side-lying hip abduction with and without visual biofeedback, the EMG activities of all measured muscles were recorded for 5 s. The mean value of the three trials under each condition was used for data analysis.

Measures of pelvic elevation

To measure pelvic elevation, a 4D-MT Motion Sensor (Relive Co., Ltd., Gimhae, South Korea;) was attached on the anterior superior iliac spine, the most prominent bony landmark of pelvis with minimal skin artifact [14, 15], on the side of hip abduction. The sampling rate was set at 25 Hz. During side-lying hip abduction, the motion data were transferred in real time to a tablet PC with 4D-MT analysis software (Relive Co., Ltd.). In the present study, we only used motion in the frontal plane to measure amount of ipsilateral pelvic elevation. The sensor tilting angle was calibrated as 0° when the hip was aligned in the neutral position using goniometer.

Side-lying hip abduction exercises

All subjects first performed side-lying hip abduction exercises without visual biofeedback, followed by the same exercise with visual biofeedback to minimize learning effects. For side-lying hip abduction exercises without visual biofeedback, the subjects were placed in front of a wall in the side-lying position. In the start position, the uppermost lower extremity was in the neutral position, while the hip and knee of the lowermost lower extremity were flexed. Subjects were asked to abduct the uppermost hip to 30° of hip abduction. A target bar was used to control the amount of hip abduction. When the ankle of the uppermost lower extremity touched the target bar, subjects held this position for 5 s.

For side-lying hip abduction exercise with visual biofeedback, subjects were placed in the same position. However, they were instructed to monitor changes in the sensor angle during hip abduction, and were asked to perform 30° of hip abduction while keeping the senor as close to 0° of tilt as possible.

The hip abduction exercises were repeated three times for each condition (without visual biofeedback and with visual biofeedback). Instruction and monitor of each exercise was performed by one examiner, while measurements of outcomes were performed by the other examiner.

Statistical analysis

PASW Statistics 18 (SPSS Inc., Chicago, Illinois) was used for statistical analysis. The mean value of EMG of the gluteus medius, quadratus lumborum, and multifidus, as well as the ipsilateral pelvic elevation angle between side-lying hip abduction exercises with and without visual biofeedback, were analyzed using a paired t-test. The significance level was set at $p < .05$.

RESULTS

Significant increases were observed in EMG activity of the gluteus medius ($p = .002$), quadratus lumborum ($p = .022$), and multifidus ($p = .020$) when the exercise was performed with visual biofeedback compared to without visual biofeedback (Table 1). Additionally, ipsilateral pelvic elevation was significantly decreased with visual biofeedback compared to without visual biofeedback ($p = .001$) (Table 1).

DISCUSSION

Our findings demonstrate that using visual biofeedback to monitor ipsilateral pelvic elevation could increase the EMG activity of the trunk and hip muscles while decreasing ipsilateral pelvic elevation during side-lying hip abduction exercises. Ipsilateral pelvic elevation was significantly decreased, and gluteus medius muscle activity was significantly increased, when the side-lying hip abduction exercise was performed in conjunction with visual biofeedback. These findings suggest that visual biofeedback is effective for correcting faulty movements during muscle isolation exercises. The previous study investigated the amount of trunk translation, with and without visual biofeedback on trunk movement, during treadmill walking in young and older healthy subjects; [16] the authors found that visual biofeedback significantly decreased trunk translation in both groups [16]. In another study, Nyman and Armstrong [17] found that visual biofeedback significantly increased knee separation and knee flexion during a drop landing test compared to the group that performed the test without biofeedback. These previous findings support the hypothesis that real-time visual biofeedback improves the movement of specific joints or segments during dynamic tasks.

In the present study, subjects monitored their ipsilateral pelvic elevation using a motion sensor. The findings suggest that the application of visual biofeedback on pelvic motion caused a decrease in ipsilateral pelvic elevation during side-lying hip abduction. The increased gluteus medius muscle activity may have resulted from a decrease in pelvic elevation caused by the application of visual biofeedback. Ipsilateral pelvic elevation allows elevation of the uppermost lower extremity without proper hip joint movement (i.e., abduction) and muscle engagement during side-lying hip abduction. In contrast,

Table 1. EMG activity of the trunk and hip muscles and the angle of ipsilateral pelvic elevation during a side-lying hip abduction exercise.

	Side-lying hip abduction without visual biofeedback	Side-lying hip abduction with visual biofeedback	P
Gluteus medius (%MVIC)	30.84±10.55	38.70±15.17	0.002*
Quadratus lumbroum (%MVIC)	23.83±10.25	31.22±14.55	0.022*
Multifidus (%MVIC)	23.63±9.53	35.05±18.81	0.020*
Ipsilateral pelvic elevation (°)	6.97±1.90	4.61±1.85	0.001*

*$p < 0.05$.

decreased ipsilateral pelvic elevation requires greater hip joint movement to elevate the lower extremity to the same height. Because the amount of elevation of the lower extremity during side-lying hip abduction was controlled by a target bar at the same height with and without visual biofeedback, it is possible that decreased ipsilateral pelvic elevation increases hip joint movement and subsequently the activity of the gluteus medius.

In addition to the gluteus medius, activity of the multifidus was significantly increased during side-lying hip abduction with visual biofeedback. Although the previous study found a change in EMG activity of the gluteus medius and quadratus lumborum with the application of pelvic motion visual biofeedback, it did not measure changes in multifidus muscle activity [11]. The multifidus is one of the most important trunk stabilizer muscles, and contraction of the multifidus may affect co-contraction of other trunk stabilizer muscles via the thoracolumbar fascia [8, 18]. Considering the simultaneous increase in multifidus muscle activity, it is possible that visual biofeedback to decrease ipsilateral pelvic elevation also helps facilitate active pelvic stabilization. Previous studies have demonstrated that both passive pelvic stabilization using a pelvic belt and active pelvic stabilization using an abdominal draw-in maneuver (ADIM) increase gluteus medius muscle activity while decreasing quadratus lumborum muscle activity during side-lying hip abduction [3, 4]. These previous findings are inconsistent with our findings of increased EMG activities in both the gluteus medius and quadratus lumborum. This disagreement may have resulted from a difference in trunk muscle recruitment patterns. There are two methods for active lumbo-pelvic stabilization: one is the ADIM that focuses on selective activation of deep muscles [4, 8], and the other is the abdominal bracing maneuver that contracts both deep and superficial muscles [19, 20]. The previous research has revealed that both the ADIM and abdominal bracing decrease compensatory lumbar extension and anterior pelvic tilt during prone hip extension [19], and also that both the ADIM and abdominal bracing lead to greater co-contraction of the multifidus compared to a control condition in the supine, quadruped, and upright standing positions, while greater co-contraction of the multifidus was found during abdominal bracing compared to ADIM in the supine position [20]. Because the ADIM requires selective activation of deep muscles, it is difficult to perform a precise ADIM without feedback on changes in contraction of the deep muscles. In contrast, abdominal bracing requires global contraction of the trunk muscles, so this maneuver is easier to perform. In the present study, it is likely that subjects used abdominal bracing to limit pelvic elevation, which resulted in an increase in multifidus muscle activity during side-lying hip abduction with visual biofeedback. The increases in EMG activity of both the quadratus lumborum and multifidus during side-lying hip abduction with visual biofeedback support our hypothesis that subjects may have used the abdominal bracing maneuver. In previous research, the increased EMG activity observed in both the quadratus lumborum and multifidus occurred only during the abdominal bracing condition, compared to the ADIM and control conditions during side-lying hip abduction [21]. Therefore, we infer that subjects used the abdominal bracing maneuver when applying visual biofeedback, which increased the EMG activity of not only the multifidus but also the quadratus lumborum.

This study had several limitations. First, we inferred that subjects may have used the abdominal bracing maneuver to control pelvic motion, but we did not specifically evaluate this muscle contraction maneuver. Second, we did not measure changes in the EMG activity of other hip abductor muscles, such as the tensor fasciae latae, and trunk stabilizer muscles, such as transversus abdominis, during side-lying hip abduction with visual biofeedback. Future study needs to measure EMG activities of these muscles to clarify the influences of controlled pelvic motion using visual biofeedback on hip and trunk muscles.

CONCLUSION

This study demonstrated that the application of visual biofeedback on pelvic motion increases EMG activity in the gluteus medius, quadratus lumborum, and multifidus, while decreasing ipsilateral pelvic elevation during a side-lying hip abduction exercise. These findings suggest that the application of pelvic motion biofeedback could change the pattern of trunk and hip muscle activation and decrease compensatory pelvic motion during side-lying hip abduction exercises.

ACKNOWLEDGMENT

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT)(No. 2018R1C1B5085529).

REFERENCES

1. Distefano LJ, Blackburn JT, Marshall SW, et al. Gluteal muscle activation during common therapeutic exercises. J Orthop Sports Phys Ther 2009; 39(7): 532–40.
2. McBeth JM, Earl–Boehm JE, Cobb SC, et al. Hip muscle activity during 3 side–lying hip–strengthening exercises in distance runners. J Athl Train 2012; 47(1): 15–23.
3. Park KM, Kim SY, Oh DW. Effects of the pelvic compression belt on gluteus medius, quadratus lumborum, and lumbar multifidus activities during side–lying hip abduction. J Electromyogr Kinesiol 2010; 20(6): 1141–5.
4. Cynn HS, Oh JS, Kwon OY, et al. Effects of lumbar stabilization using a pressure biofeedback unit on muscle activity and lateral pelvic tilt during hip abduction in sidelying. Arch Phys Med Rehabil 2006; 87(11): 1454–8.
5. Macadam P, Cronin J, Contreras B. An examination of the gluteal muscle activity associated with dynamic hip abduction and hip external rotation exercise: a systematic review. Int J Sports Phys Ther 2015; 10(5): 573–91.
6. Neumann DA. Kinesiology of the Musculoskeletal System: Foundations for Rehabilitation, 3rd ed. Elsevier, St Louis. 2017.
7. Page P, Frank CC, Lardner R. Assessment and Treatment of Muscle Imbalance: The Janda Approach. Human kinetics, Champaign. 2010.
8. Richardson C, Hodges P, Hides J. Therapeutic Exercise for Lumbopelvic Stabilization: A Motor Control Approach for the Treatment and Prevention of Low Back Pain, 2nd ed. Churchill Livingstone, Edinburgh. 2004.
9. Hwang UJ, Kwon OY, Jung SH, et al. Predictors of pain intensity and Oswestry Disability Index in prolonged standing service workers with nonspecific chronic low back pain subclassified as active extension pattern. Musculoskelet Sci Pract 2019; 40: 58–64.
10. Jung SH, Kwon OY, Yi CH, et al. Predictors of dysfunction and health–related quality of life in the flexion pattern subgroup of patients with chronic lower back pain: The STROBE study. Medicine (Baltimore) 2018; 97(29): e11363.
11. Kang MH, Kim SY, Yu IY, et al. Effects of real–time visual biofeedback of pelvic movement on electromyographic activity of hip muscles and lateral pelvic tilt during unilateral weight–bearing and side–lying hip abduction exercises. J Electromyogr Kinesiol. 2019 Jun 10; 48: 31–6. Epub ahead of print.
12. Criswell E. Introduction to Surface Electromyography, 2nd ed. Jones and Bartlett Publishers, Sudbury. 2010.
13. Hislop HJ, Avers D, Brown M. Daniels and Worthingham's Muscle Testing: Techniques of Manual Examination and Performance Testing, 9th ed. Elsevier, St. Louis. 2013.
14. Schache AG, Blanch P, Rath D, et al. Three–dimensional angular kinematics of the lumbar spine and pelvis during running. Hum Mov Sci 2002; 21(2): 273–93.
15. Schache AG, Wrigley TV, Blanch PD, et al. The effect of differing Cardan angle sequences on three dimensional lumbo–pelvic angular kinematics during running. Med Eng Phys 2001; 23(7): 493–501.
16. Anson E, Rosenberg R, Agada P, et al. Does visual feedback during walking result in similar improvements in trunk control for young and older healthy adults? J Neuroeng Rehabil 2013; 10: 110.
17. Nyman E Jr, Armstrong CW. Real–time feedback during drop landing training improves subsequent frontal and sagittal plane knee kinematics. Clin Biomech (Bristol, Avon) 2015; 30(9): 988–94.
18. Hodges PW. Is there a role for transversus abdominis in lumbo–pelvic stability? Man Ther 1999; 4(2): 74–86.
19. Suehiro T, Mizutani M, Watanabe S, et al. Comparison of spine motion and trunk muscle activity between abdominal hollowing and abdominal bracing maneuvers during prone hip extension. J Bodyw Mov Ther 2014; 18(3): 482–8.
20. Matthijs OC, Dedrick GS, James CR, et al. Co–contractive activation of the superficial multifidus during volitional preemptive abdominal contraction. PM R 2014; 6(1): 13–21.
21. Kim DW, Kim TH. Effects of abdominal hollowing and abdominal bracing during side–lying hip abduction on the lateral rotation and muscle activity of the pelvis. J Exerc Rehabil 2018; 14(2): 226–30.