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Effects of Lumbar Stabilization Using Pressure Biofeedback Unit During Hip Abduction in Side-Lying in Patients With Low Back Pain

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Abstract

Background: Lumbar stabilization (LS) improve the thickness of the quadratus lumborum (QL) muscle and muscle activity of the gluteus medius (GM) muscle during hip abduction in a side-lying position in patients with low back pain (LBP).

Objects: The purpose of this study was to assess the effects of LS on muscle thickness of QL and muscle activity of GM during hip abduction in side-lying in patients with LBP.

Methods: The study included 32 patients with LBP, who were randomly divided into the control group and experimental group, each with 16 patients. All subjects performed 35° preferred hip abduction (control group) and 35° hip abduction with LS (experimental group) during side-lying. An ultrasonography and a surface electromyography were used to measure the thickness of the QL muscle, and the muscle activities of the GM muscle respectively. Independent t-test was used to compare the muscle thickness of the QL and the muscle activity of the GM muscle, respectively.

Results: Anterio-posterior diameter in the muscle thickness of QL muscle was decreased significantly in hip abduction with LS more than in preferred hip abduction ($p<.001$), but medio-lateral diameter in the muscle thickness of QL muscle was not significantly different between in preferred hip abduction and in hip abduction with LS ($p=.06$). The muscle activity of GM was increased significantly in hip abduction with LS more than in preferred hip abduction ($p<.001$).

Conclusion: These findings suggest that hip abduction with LS could be recommended as a hip abduction for LS and a prevention unwanted compensatory pelvic lateral tilting movement.

Key Words: Gluteus medius; Hip abduction; Quadratus lumborum; Ultrasonography.

Introduction

One of the causes of the low back pain (LBP) is an instability of the lumbar segment (Panjabi, 2003). This instability can cause disequilibrium in the movement of lumbar system (Comerford and Mottram, 2001). The disequilibrium with decreasing joint mobility of the lower extremity in LBP could be observed during the activities of sitting, standing and walking. And, the improper control of joint mobility in the spine and lower extremities, could cause the pain of the lumbo-pelvic-hip complex (Hoffman et al, 2011).

The dysfunctional movement of the gluteus medius (GM) muscle is related to several musculoskeletal disorders of the lumbo-pelvic-hip complex (O'Sullivan et al, 2010). According to previous research, the GM muscle in patients with chronic LBP was weak and rapidly fatigued (Arab and Nourbakhsh, 2010). For example, the height difference in hip joint and pain around the hip joint in patients with LBP is caused by weakness of the GM muscle (Sahrmann, 2002). Additionally, weakness of the GM muscle can cause the lateral bending of the trunk during one leg standing (Neumann, 2010). Thus, rehabilitation management of the muscles around the hip joint should be considered a strategic approach in lumbar stabilization (Nelson-Wong and Callaghan, 2010). Specifically, improving the function of the GM muscle will improve

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neuromuscular coordination of the lumbo-pelvic-hip complex and prevent LBP (Fredericson et al, 2000).

Janda et al (1996) report that compensatory movements such as hip flexion, hip external rotation and pelvic lateral tilting should not occur until the hip joint reaches 40° of abduction. When the GM muscle is weakened, a synergist such as the quadratus lumborum (QL) muscle can be used to compensate and pelvic lateral tilting can occur (Comerford and Mottram, 2001). Similarly, the muscle activity of the QL muscle is increased due to excessive use, it may cause lumbar lateral flexion by pelvic elevation, which results in instability or impairment of the lumbo-pelvic-hip complex system (Sahrmann, 2002).

Most of the studies related to core stability measurements have been conducted with the subjects in a supine position. In previous studies, hip abduction measurements in a side-lying position using pressure biofeedback unit (PBU) have been finitely presented in patients with LBP. Therefore, research related to the hip abduction mechanisms underpinning the effects of core stability to the selective recruitment of the GM muscle associated excluding the compensatory movement of the QL muscle in a side-lying position is much needed.

This study was undertaken to determine the additive effect of core stability and hip abduction in a side-lying position for LBP patients. To quantitatively investigate the mechanism of core stability on muscle thickness and associated muscle activity, our study has been undertaken for patients with LBP using the real-time ultrasound (US) imaging technique and electromyography (EMG) technique. Our basic hypothesis was that the decrease in size of the QL muscle and increase in amplitude in the GM muscle would significantly improve in the experimental group (which performed both the hip abduction and core stability exercises) than the control group (which performed the hip abduction alone).

Methods

Subjects

A convenience sample of thirty-two patients with LBP was recruited from local private center (Daejeon, South Korea). All the procedures were explained to the subjects, and each subject signed an informed consent form. General characteristics of the subjects are presented (Table 1). The inclusion criteria were as follows: (1) persistent LBP for at least 3 months (Airaksinen et al, 2006), (2) average pain intensity over the last 2 weeks <3 point on 10 point of Visual Analogue Scale, (3) 10~25 point on 50 point of Oswestry Disability Index, (4) failure of the abdominal draw in maneuver (ADIM) formal test (considered “failure” when the participant was unable to reduce and maintain a 5~10 ㎜Hg difference in the PBU during 10 seconds in the side-lying ADIM formal test) (von Garnier et al, 2009). The exclusion criteria were as follows: (1) below good grade of GM muscle on manual muscle testing, (2) diagnosis of other neurologic disorders that may affect this study, (3) severe cardiovascular diseases, (4) osteoporosis, structural deformity, systemic inflammatory disease, and nerve root compression that could affect the experimental tests (Powers et al, 2008).

Table 1. Demographic and clinical characteristics of the patients (N=32)

Parameters	Control group (n_1=16)	Experimental group (n_2=16)	t	p
Age (year)	28.9±4.3[a]	30.6±10.4	.622	.539
Height (㎝)	168.3±7.2	163.3±7.2	-1.961	.059
Weight (㎏)	64.7±15.7	58.1±10.3	-1.410	.169
VAS[b]	2.5±.5	2.6±.6	.307	.761
ODI[c]	10.4±1.5	10.3±1.1	-.399	.693

[a]mean±standard deviation, [b]visual analogue scale, [c]Oswestry disability index.

Procedure

Each subject was positioned in a side-lying position with their non-dominant knee joints slightly flexed. All subjects were right leg dominant. They were positioned straight on a manual table. The lumbar spine was in a neutral position. Two positions were assessed: (1) preferred hip abduction (PHA) (Figure 1) and hip abduction with lumbar stabilization (HALS) (Figure 2). The PHA position involves a 35° abduction of the dominant hip while side-lying. The HALS position is an ADIM using a PBU with a 35° abduction of the dominant hip while side-lying (Cynn et al, 2006). The EMG activity and US thickness were measured in the GM and QL muscles, respectively, while performing the hip abduction of the dominant lower extremity while side-lying. The non-dominant lower extremity could be slightly flexed at the knee joints. The subject was asked to perform a hip abduction while side-lying with the dominant lower extremity in the preferred condition, with and without the PBU. A digital inclinometer (Dualer IQ Inclinometer, J-Tech Medical, Heber city, USA) was used to determine the 35° angle for hip abduction. To control the individual variability in hip abduction range, a target bar was placed at the level of 35° of hip abduction (Cynn et al, 2006). In the lumbar stabilization condition, the PBU was placed between the therapeutic table, which has a firm mattress, and the subject's lumbar spine in the side-lying position. The PBU was inflated until the pressure level was approximately 40 ㎜Hg, at which point the target pressure was determined. Pressure changes of 5 ㎜Hg were allowed to account for changes induced by respiration (Cynn et al, 2006).

Prior to testing, all subjects were trained for approximately 10 min to familiarize themselves with the PHA and HALS positions, until they demonstrated proficiency. When the hip was placed at 35° of abduction, the participants maintained the ADIM posture and normal respiration. At 2/3 of the participant's normal expiration they were asked to hold the position for 5 seconds. US images of the QL muscle were collected during this 5 seconds period. There was a 5 min rest between each trial. The subjects were not provided with any biofeedback regarding their performance or results for any trials.

After a 30 min rest, an electrode was attached to collect EMG data from the GM muscle. The subjects were asked to perform the PHA and HALS positions in the same manner. All examinations were conducted by the same researcher.

Ultrasonography and data processing

This study used US equipment (Achievo CST, V2U Healthcare, Pte, Ltd. Midview city, Singapore). Using a 3.5 ㎒ convex transducer, the thicknesses of the QL muscle on the dominant side was measured during the PHA and HALS periods. The thickness of the QL muscle was measured by US imaging due to muscle depth in this study. To measure the QL muscle, the transducer was moved laterally from the transverse plane at the L3 level until an image was obtained (Reeve and Dilley, 2009). The thickness of the QL muscle was measured at the medio-lateral (M-L) and anterio-posterior (A-P) diameters at the widest point (Desmoulin and Millner, 2007) (Figure 3). The location of the transducer head was marked so that the identical placement would be used for all measurements. All US images were collected at the

Figure 1. Preferred hip abduction.

Figure 2. Hip abduction with lumbar stabilization.

end of the posture while the subject was holding his or her breath after expiration, and the images were stored. Each measurement was repeated thrice and the average was used.

Surface EMG recording and data processing

EMG was recorded using the TeleMyo 2400T Direct Transmission System (DTS), and analysis was completed using Myo-research software (Noraxon Inc., Scottsdale, AZ, USA). EMG channel recorded the muscle activity of the dominant side GM muscle. The surface EMG measurement for the GM muscle was used due to the superficial location in this study. The skin was shaved with a razor and cleaned with rubbing alcohol to minimize the effects of contamination. Disposable Ag-AgCl surface electrodes were positioned at an inter-electrode distance of 2 ㎝. EMG data were collected over the proximal third of the distance between the iliac crest and the greater trochanter ipsilateral to the dominant side GM muscle (Criswell, 2010) (Figure 4). The sampling frequency of raw EMG signals was 1000 ㎐. A band-pass filter (20∼500 ㎐) and notch filter (60 ㎐) were used. EMG data were converted to root mean square (RMS) values. The mean RMS at the maximal voluntary isometric contraction (MVIC) was recorded from each subject for 5 seconds, thrice, with a 5 min rest interval. The GM muscle was contracted as hard as possible in a manual muscle-testing position (Kendall et al, 2005). The data were expressed as a percentage of the MVIC (%MVIC), and the mean value of three trials was used for data analysis.

Statistical analysis

The descriptive statistics including the means and standard deviations were used in general characteristics. Independent t-test was used to determine significant differences in muscle thicknesses of the QL muscle and muscle activity of the GM muscle between PHA (control group) and HALS (experimental group). The alpha level of statistical significance was set at .05. All the data were analyzed using the SPSS version 18.0 (SPSS Inc., Chicago, IL, USA).

Results

The independent t-tests revealed that the A-P thickness of QL muscle was significantly decreased in experimental group (HALS) compared with control group (PHA) ($p<.001$), however, the M-L thickness of QL muscle was not significantly decreased in experimental group (HALS) compared with control group (PHA) ($p=.06$) (Table 2).

The independent t-tests showed that the muscle activity of GM muscle was significantly increased in experimental group (HALS) compared with control group (PHA) ($p<.001$) (Table 3).

Discussion

This study demonstrated whether core stabilization could improve the thickness of the QL muscle and muscle activity of the GM muscle during hip abduc-

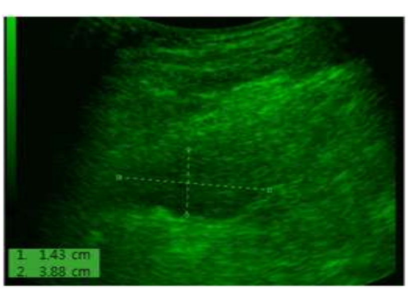

Figure 3. Measurement of quadratus lumborum muscle thickness.

Figure 4. Placement of EMG electrodes on gluteus medius.

Table 2. Comparison of muscle thicknesses of quadratus lumborum muscle between control group (preferred hip abduction) and experimental group (hip abduction with lumbar stabilization) (Unit=㎝)

Muscle thickness	Control group (n_1=16)	Experimental group (n_2=16)	t	p
QL (A-P)[a]	1.53±.34[b]	1.38±.31	6.35	<.001*
QL (M-L)[c]	3.91±.65	3.77±.70	1.96	.06

[a]quadratus lumborum (anterio-posterior), [b]mean±standard deviation, [c]quadratus lumborum (medio-lateral), *p<.05.

Table 3. Comparison of EMG muscle activity of gluteus medius muscle between control group (preferred hip abduction) and experimental group (hip abduction with lumbar stabilization) (Unit=%MVIC)

Muscle	Control group (n_1=16)	Experimental group (n_2=16)	t	p
GM[a]	38.10±12.55[b]	47.90±12.44	-5.28	<.001*

[a]gluteus medius, [b]mean±standard deviation, *p<.05.

tion in a side-lying position in patients with LBP. As anticipated, the thickness of the QL muscle was significantly decreased and the activity of the GM muscle was significantly increased in the experimental group (HALS) compared to the control group (PHA) as a function of the core stability effect. Intervention related changes in altered muscle thickness were successfully quantified by US imaging technique. This morphological decrease in muscle thickness was paralleled with increased EMG muscle activity of GM muscle during HALS. Such functional improvements were corroborated by pelvic elevation instigated by the activation of the QL muscle without core stabilization.

Core stabilization plays a key role in various positions such as quadruped, prone on elbow, push up, bridging and side-lying during the performance of activities of daily living in patients with LBP (Zazulak et al, 2007). In particular, core stabilization must be actively present when performing any task that involves hip abduction in side-lying in patients with LBP. Namely, the core stabilizer muscles must be able to obtain the correct pattern like a length and muscle activity, which to stabilize the proximal attachment region of the lower extremity muscles such as the QL and GM. Therefore, the correct QL and GM muscle functions are needed to achieve core stabilization during hip abduction in a side-lying position.

The changes in muscle thickness were successfully quantified with US imaging. This morphological improvement in muscle thickness was paralleled by an increase in muscle activity of the GM muscle during hip abduction in a side-lying position. US imaging is useful for evaluating muscle size by measuring the change in static and dynamic movement during muscle contraction (Kiesel et al, 2007). Real-time US is relatively inexpensive, safe, and comfortable, and hence has been widely advocated for in the diagnostic examination of morphological changes in the muscles or muscular pathology (McMeeken et al, 2004). Teyhen (2006), emphasized that US is a non-invasive clinical method. Furthermore, to our knowledge, previous imaging studies have been limitedly attempted to elucidate the clinical progress associated with core stability in patients with LBP.

Surface EMG has primarily been used to monitor the superficial trunk muscles, such as the rectus abdominis and external oblique (Dickstein et al, 2004). There are limitations to measuring the activity of the deep core muscles such as the transverse abdominis, multifidus, and QL muscles. Fine-wire EMG can be used to observe the precise activity of deep muscles and provide more accurate measurements. However, this is an invasive method that can cause pain and inflammation (Hodges and Richardson, 1997). In addition, Cynn et al (2006), reported that the QL muscle could be measured with surface EMG, though the cross-talk frequency will be higher due to the deep location of the QL muscle.

The QL (A-P) thickness measured with US imaging, was 1.53 ㎝ and 1.38 ㎝ during PHA and HALS, respectively. The QL (M-L) thickness was 3.91 ㎝ and 3.77 ㎝ during PHA and HALS, respectively. Consequently, the muscle thickness was decreased by approximately 10% during HALS. These results indicate that core stabilization may be provided a neutral pelvic tilt during hip abduction in a side-lying position under the HALS condition. The muscle activity of the GM muscle measured by surface EMG, was 38 %MVIC and 47 %MVIC during PHA and HALS, respectively. The muscle activity of the GM muscle was increased by approximately 24% during HALS. These results indicate that core stabilization is able to decrease the compensatory action of the QL muscle while selectively facilitating GM muscle activity under the HALS condition. Similarly, Cynn et al (2006), reported that the muscle activity of the GM muscle demonstrated an 84% improvement in the group that performed core stability. As the activity of the QL muscle was increased in the PHA condition without core stability, the angle of pelvic lateral tilt likely also increased. During a core stabilization movement, this may be partly caused by the inhibition of a superficial global muscle such as the QL muscle as well as the activation of the core muscles.

Our results confirm the hypothesis that core stabilization during hip abduction in a side-lying position can reduce QL muscle activity and ipsilateral pelvic tilt, resulting in increased the muscle activity of the GM muscle. Previous studies have recommended a treatment protocol that includes relaxation to decrease the activity of the QL muscle and exercise to facilitate the recruitment of the GM muscle (Cynn et al, 2006). Namely, lumber core stabilization technique used here could stabilize the pelvis and recruit the GM muscle without compensation from the QL muscle. Therefore, we suggest that core stabilization while side-lying is useful in protocols designed to prevent motor control dysfunction by reducing the muscle activity of the QL muscle and strengthening the GM muscle.

Specifically, core stability stabilizes the proximal segment such as the trunk, and activates the mobility of the distal parts such as the pelvic limb (Carroll et al, 2006). The mobility of the limbs without core stability can cause instability of the proximal area, the appropriate movement cannot be performed (Comerford and Mottram, 2001). As lumbopelvic stability is improved via increased the muscle activity of the GM muscle, the substitution action of the QL muscle is inhibited. This is associated with the PBU as it is applied. Additionally, the surface EMG data of this study are consistent with the findings of Cynn et al (2006), who studied the effect of core stabilization on muscle activity of the GM muscle during hip abduction in a side-lying position in patients with LBP.

This study has some limitations that should be addressed in a larger clinical study. First, the GM muscle could not be measured on the US image because the attachment region at the greater trochanter of the femur was obscured on the medial side during hip abduction. Second, the US image technique used to measure the entire shape of the muscle had a limited viewing angle as measured; when the QL muscle was not flexed there is some difficulty in obtaining an image in the same position when the measuring position is moved. Third, US images were not measured between men and women in this research despite of sex difference on the thickness of QL muscle. Lastly, the results of this study cannot be generalized to other populations due to the limited sample size and research design. Therefore, further studies are warranted to assess deep muscle activity during hip abduction training while side-lying with core stabilization and to determine the direct benefit and selective muscle facilitation associated with core stabilization.

Conclusion

This study was designed to examine the effect of HALS method of core stabilized without compensatory movement in patients with LBP. The results show that the thickness of the QL muscle was decreased and the activity of the GM muscle was increased during the performance of hip abduction in the side-lying position in patients with LBP with core stabilization achieved using a PBU. Our findings suggest that hip abduction movements require core stabilization to prevent unwanted compensatory action by the QL muscle and to selectively facilitate the GM muscle.

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