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Effects of Lumbar Stabilization on the Trunk and Lower Limb Muscle Activity and Velocity of the Center of Pressure During Single Leg Standing

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Abstract

The aim of this study was to investigate the effects of lumbar stabilization on both trunk and lower limb muscle activity and center of pressure (COP) in single leg standing. Surface electromyography (EMG) was used to collect muscle activity data, the mean velocity of COP was measured using a force plate, and a pressure biofeedback unit was used for lumbar stabilization training. The findings of this study are summarized as follows: 1) The EMG activity of the erector spinae decreased significantly and the activity of the rectus abdominis, internal oblique, external oblique, gluteus maximus, and gluteus medius increased significantly with lumbar stabilization single leg standing. 2) No differences in activity in the tibialis anterior, medial gastrocnemius, rectus femoris, and medial hamstrings were found with single leg standing. 3) The mean velocity of COP in the antero-posterior and medio-lateral directions in the lumbar stabilization single leg standing decreased significantly compared with the preferred single leg standing. The findings of this study therefore indicate that lumbar stabilization can facilitate the co-activation of deep stabilization and global muscles that improve postural control capability during single leg standing.

Key Words: Center of pressure; Lumbar stabilization; Muscle activity; Single leg standing.

Introduction

Lumbar stabilization is a therapeutic approach to provide stability to the lumbar region through deep segmental muscles and has been introduced to prevent and treat musculoskeletal injuries (Akuthota and Nadler, 2004; Kisner and Colby, 2002). The stability of the spine is maintained by three subsystems: the passive, active, and control subsystems (Panjabi, 1992a). Among these, local muscle contraction is of particular importance, as it provides dynamic stability to the neutral zone (Panjabi, 1992b), whereas the transversus abdominis and the multifidus contribute to lumbar stabilization (Barnett and Gilleard, 2005; Richardson et al, 1999; Richardson et al, 2004). Richardson and Jull (1995) reported that deep muscles should co-contract; otherwise, excessive substitute motions will occur. Learning lumbar stabilization through cognitive repetition facilitates the automatic co-contraction of deep muscles while performing daily activities (Saal and Saal, 1989).

The pressure biofeedback unit was originally developed to assess the level of lumbar stabilization through the deep abdominal muscles and has been utilized in previous research evaluating lumbar stability (Herrington and Davies, 2005; Jull et al, 1993; Mills et al, 2005; Richardson et al, 1992; Wohlfart et al, 1993). This device consists of an inflatable cushion, a bulb, and a pressure gauge and is reported to provide reliable and valid measurement of local stabilizing muscles (Cairns et al, 2000; Richardson and Jull, 1995). The pressure biofeedback unit is applied to the lumbar region of the subject and inflated to the target pressure. While the subject performs the prescribed exercise, the target pressure is maintained. Failure to sustain the target pressure indicates an inability to perform lumbar

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stabilization or an increase in intra-abdominal pressure.

Postural control is defined as the ability to maintain the center of gravity within the base of support. An unstable platform and perturbations were used to identify the variables affecting this balance. Single leg standing is a more unstable posture as the center of mass is located high and the base of support is narrow relative to double leg standing. The capability to sustain a single leg standing position is required for many activities of daily living (Jonsson et al, 2004) and as such, single leg standing has been implemented for clinical tests and intervention in previous studies (Fritz and George, 2000; Liebenson, 2005; Tidstrand and Horneij, 2009). However, the effects of lumbar stabilization on muscle activity and the velocity of the center of pressure (COP) during single leg standing have not been extensively studied. Because lumbar instability (Hungerford et al, 2003) as well as insufficient muscle strength of the trunk or the lower limbs has been reported to diminish postural control (Szklut and Breath, 2001), examining the effects of lumbar stabilization achieved by using the pressure biofeedback unit will provide clinically relevant information in the physical therapy field.

The aim of this study was to identify the effects of lumbar stabilization on both muscle activity and the velocity of COP in the antero-posterior and medio-lateral directions during single leg standing. It was hypothesized that both muscle activity and COP would be reduced during single leg standing with lumbar stabilization.

Methods

Subjects

A sample of 20 young healthy males voluntarily participated in this study. The subjects were excluded if they displayed a past or present history of musculoskeletal injury, lower limb deformity, or orthopedic or neurological disorders that would affect single leg standing. All subjects provided written, informed consent, and the study was approved by the University Research Ethical Committee.

Measurement Instruments

Surface electromyography

Surface electromyography (EMG)[1)] was used to measure the muscle activity of the lower limb. Acqknowledge 3.7.1 software was used for data analysis. A bipolar surface electrode with a diameter of 1 ㎝ and an inter-electrode distance of 2 ㎝ was used (TSD 150B, BIOPAC Systems Inc., CA, U.S.A.). A disposable surface electrode (EL503, BIOPAC Systems Inc., CA, U.S.A.) with a diameter of 1 ㎝ was also used in the study.

The site of electrode placement was shaved and sanded to reduce skin resistance. An electrolyte gel was applied to the electrode and double adhesive tape was attached. A bipolar surface electrode was placed onto the dominant tibialis anterior (proximal to 75% of the line connecting the lateral condyle of the knee joint and the lateral malleolus), medial gastrocnemius (proximal to 30% of the line connecting the lateral condyle of the knee joint and the calcaneus), rectus femoris (midpoint between the anterior superior iliac spine and the patellar apex), biceps femoris (midpoint between the ischial tuberosity and the lateral epicondyle), gluteus maximus (midpoint between the greater trochanter and the second sacral vertebra), gluteus medius (proximal to 30% of the distance between the iliac crest and the greater trochanter), rectus abdominis (midpoint between the umbilicus and the pubis), internal oblique (midpoint between the anterior superior iliac crest and the symphysis pubis and proximal to the inguinal ligament), external oblique (5 ㎝ lateral to the umbilicus), and the erector spinae (midpoint between the first lumbar spinous process and the lateral aspect of trunk); all were placed on the dominant side (Cram et al, 1998). Ground electrodes were attached to the dominant fibular head.

The sampling rate was 1024 ㎐, and a bandpass filter (20～450 ㎐) was used. The raw myoelectric

1) MP100A-CE, BIOPAC Systems Inc., CA, U.S.A.

signal collected was processed to the root mean square. The maximal voluntary isometric contraction (MVIC) described by Kendall et al (2005) was used to determine the reference contraction.

Force plate

A force plate[2] was used to measure COP (.4×.6 ㎡). The sampling rate was 120 ㎐, and the collected data were analyzed using a Kistler control unit (Kistler Bioware Software, Kistler Instruments, Winterthur Wülflingen, Switzerland). The mean COP velocity in the antero-posterior and medio-lateral directions was then calculated.

Procedure

Each subject was asked to stand on the force plate with his feet shoulder width apart. Following a verbal command from the principal investigator, the subject flexed the non-dominant hip to 60° and relaxed the knee joint to hang vertically while bearing his weight on the dominant lower limb. The arms were folded across the chest, and subjects were directed to maintain a forward-looking position. While balance was maintained for 10 seconds in the single leg standing position, muscle activity and the mean velocity of COP in the antero-posterior and the medio-lateral directions were measured. If the subject moved the dominant foot to maintain balance or was unable to maintain the single leg standing position, the data were not included in subsequent analyses. The initial and final 2 second were discarded, and the remaining 6 second of data were recorded. The mean of three trials was calculated, with a 5 minute resting period between trials to minimize fatigue.

Following data collection in the preferred single leg standing position, lumbar stabilization training was undertaken using a pressure biofeedback unit with subjects in the supine, sidelying, and prone positions. Lumbar stabilization training was performed for a 30 minute period each day for 2 days. The pressure biofeedback unit was placed between the lumbar region and the treatment table for the supine and sidelying positions and between the abdominal region and the treatment table in the prone position. The target pressure was set to 70 ㎜Hg in each position, and the subject was instructed to watch the pressure gauge while performing hip flexion in the supine position, hip abduction in the side lying position, and hip extension in the prone position. Subjects were asked to perform each hip movement while keeping the pressure gauge within the limit of 5 ㎜Hg. If a pressure change of >5 ㎜Hg occurred, the lumbar stabilization was considered to have failed. After two days of training, all subjects were able to maintain lumbar stabilization comfortably. Following the training regime, the data for the lumbar stabilization condition of the single leg standing position were collected using a procedure identical to the initial trials.

Statistical Analysis

Statistical analysis was performed using the SPSS ver. 13.0 software. A paired t-test was used to compare the muscle activity and the mean velocity of COP between the two conditions (preferred single leg standing vs. lumbar stabilization single leg standing). A p-value of $\leq .05$ was deemed significant.

Results

Characteristics of Subjects

A sample of 20 male subjects was recruited for this study. The general characteristics of subjects are presented in Table 1.

Table 1. General characteristics of subjects (N=20)

Parameter	Mean±SD
Age (yrs)	23.3±2.9
Height (㎝)	163.4±4.5
Weight (㎏)	3.8±8.5
Body mass index (㎏/㎡)	22.3±6.1

2) Kistler force plate, Kistler Instruments, Winterthur Wülflingen, Switzerland.

Comparison of Muscle Activity Between Conditions

The muscle activity of the erector spinae decreased significantly under the lumbar stabilization single leg standing position compared with the preferred single leg standing position ($p<.05$). The muscle activity of the rectus abdominis, external oblique, internal oblique, gluteus maximus, and gluteus medius increased significantly in the lumbar stabilization single leg standing position compared with the preferred single leg standing position ($p<.05$). No significant differences were found in the muscle activity of the tibialis anterior, medial gastrocnemius, rectus femoris, and biceps femoris between the preferred single leg standing and lumbar stabilization single leg standing positions ($p>.05$) (Table 2).

Comparison of Mean Velocity of COP Between Conditions

The mean velocity of COP in the medio-lateral and antero-posterior directions decreased significantly in the lumbar stabilization single leg standing position compared with the preferred single leg standing position ($p<.05$) (Table 3).

Discussion

The present study was performed to investigate the effects of lumbar stabilization on the muscle activity and mean velocity of COP during single leg standing in healthy subjects. The results presented in this study showed that the EMG activity of the erector spinae (global muscle) decreased significantly, whereas the activity of the internal oblique (deep muscle) increased significantly during single leg standing following lumbar stabilization training. Additionally, the muscle activity of the rectus abdominis, external oblique, gluteus maximus, and gluteus medius increased significantly during single leg standing with lumbar stabilization, whereas no differences were observed in the

Table 2. Comparison of muscle activity between conditions (N=20)

	Preferred single leg standing	Lumbar stabilization single leg standing
Tibialis anterior	14.62±.34[a]	12.35±.39
Medial gastrocnemius	26.56±2.20	24.68±.21
Rectus femoris	29.62±1.01	27.24±1.08
Biceps femoris	14.63±.82	16.51±1.51
Gluteus maximus	30.40±8.34	42.94±13.47*
Gluteus medius	27.84±39.49	36.85±19.37*
Rectus abdominis	6.64±2.65	13.52±3.46*
Internal oblique	9.69±3.01	26.58±2.84*
External oblique	17.67±5.34	25.54±4.98*
Erector spinae	32.62±3.94	24.82±2.12*

[a]Mean±SD (%MVIC), *Significant difference compared to preferred single leg standing.

Table 3. Comparison of mean velocity of COP between conditions (N=20)

	Preferred single leg standing	Lumbar stabilization single leg standing
Antero-posterior velocity of COP[a]	387.09±42.34[b]	297.92±34.39*
Medio-lateral velocity of COP	436.23±82.20	373.66±68.21*

[a]Center of pressure, [b]Mean±SD (㎜/s), *Significant difference compared to preferred single leg standing.

tibialis anterior, medial gastrocnemius, rectus femoris, and medial hamstrings.

The increased muscle activity of the internal oblique can be attributed to the successful implementation of the lumbar stabilization training program implemented in this study. It is well known that deep stabilizing muscles, such as the transversus and internal oblique, can be selectively activated through training with a pressure biofeedback unit (Cynn et al, 2006; Oh et al, 2007). Thus, it can be stated that the deep muscles were selectively recruited for segmental stabilization, as lumbopelvic regional stability is required during the unstable posture induced by single leg standing. Furthermore, activity in the global muscles such as the rectus abdominis and external oblique increased significantly, which did not support our research hypothesis. It was observed that the global muscles, including the rectus abdominis and external oblique, were activated concurrently with the local muscles during the various exercises (Arokoski et al, 2004; Jull et al, 1993). Furthermore, it was difficult to isolate local muscle activation from global muscle co-activation (Beith et al, 2001; Stevens et al, 2007). Therefore, the increased muscle activity in the rectus abdominis, external oblique, and internal oblique in this study is in accordance with previous studies, and both deep and global muscles contributed to the stability of the single leg standing position.

When maintaining the single leg standing position, both gluteus maximus and gluteus medius activity are required to sustain a stable posture. The lumbar stabilization applied in this study did not aim to strengthen the gluteus maximus and gluteus medius, although the muscle activities of both these muscles during single leg standing increased. Previous reports have demonstrated that an abdominal drawing-in maneuver performed using a pressure biofeedback unit successfully increased gluteus maximus muscle activity in the prone position and gluteus medius muscle activity in the side lying position in healthy control subjects (Cynn et al, 2006; Oh et al, 2007). Our findings can be therefore be interpreted as indicating that performance of lumbar stabilization using a pressure biofeedback unit activates the gluteus maximus and gluteus medius muscles, and this increased activation contributes to the postural control capability during single leg standing.

The mean velocity of the antero-posterior and medio-lateral COP in the lumbar stabilization single leg standing position significantly decreased compared with that in the preferred single leg standing position, implying improved postural control capability with lumbar stabilization. COP parameters are regarded as representing the level of postural control (Geurts et al, 1993; Geurts et al, 1996; Winter, 1995). In previous studies, the displacement, velocity, or acceleration of COP has been measured to assess postural control capability (Garland et al, 2003; Pyöriä et al, 2004). Raymakers and colleagues (2005) argued that the mean velocity of COP is a discriminating variable that determines the level of postural control among COP parameters. The location of COP represents neural control of the muscles (Winter, 1995). In the present study, although the COP parameters and the mean velocity of COP in the antero-posterior and the medio-lateral direction decreased significantly, the muscle activity of the lower leg did not decrease in the lumbar stabilization single leg standing position. Furthermore, the muscle activity of the proximal muscles (gluteus maximus and gluteus medius) increased significantly. This relationship between the mean velocity of COP and the muscle activity of the proximal and distal muscles therefore requires clarification in future studies of the single leg standing position.

Maintaining an unstable posture is required to perform normal activities of daily living, in addition to the important purposes of physical therapy intervention. Because a short period of lumbar stabilization training with a pressure biofeedback unit improved postural control and increased muscle activity in this study, it is suggested that lumbar stabilization be implemented for those who require lumbopelvic stability, particularly patients suffering from lower back pain.

The present study is not without limitations. First, we could not completely control the learning and testing effect, as comparisons were performed without randomization of subjects. Second, the subjects in this study were healthy young male adults, limiting the study's generalizability to the wider population. Third, the kinematic data of the trunk and limbs were not collected. Thus, further studies with symptomatic samples are warranted to examine the long term effects of lumbar stabilization on the general population.

Conclusion

The present study examines the effects of lumbar stabilization on both trunk and lower limb muscle activity and the mean velocity of COP during single leg standing using surface electromyography and a force plate. The EMG activity of the erector spinae decreased significantly, whereas the activity of the rectus abdominis, internal oblique, external oblique, gluteus maximus, and gluteus medius increased significantly during single leg standing following lumbar stabilization training. In contrast, no significant differences were observed in the tibialis anterior, medial gastrocnemius, rectus femoris, and medial hamstrings with lumbar stabilization during lumbar stabilization single leg standing compared with the preferred single leg standing position. In addition, the mean velocity of COP in the antero-posterior and medio-lateral directions during lumbar stabilization decreased significantly compared with that in the initial preferred single leg standing position. This study highlights lumbar stabilization as an alternative approach to both improve postural control capability and induce co-activation of the local and global muscles during single leg standing.

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