

Comparison of Abdominal and Lumbar Multifidus Muscle Activity During Unilateral Hip Extension in Prone Position on the Floor and on a Round Foam Roll

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Abstract

The purpose of this study was to compare the muscle activity of the abdominal and lumbar multifidus during unilateral prone hip extension on the floor and on a round foam roll. Fifteen healthy participants were recruited. They were instructed to perform a unilateral hip extension on the floor and on a round foam roll in the prone position. Surface electromyography (EMG) signals were recorded from bilateral lumbar multifidus (LM), external oblique (EO), and internal oblique (IO) muscles. A paired t-test was used to compare muscle activity, with the level of significance set at $\alpha=.05$. The results showed that bilateral LM, EO, IO EMG activity during right-hip extension on a round foam roll was greater than that on the floor, and EMG activity of bilateral LM, right EO, and left IO during left-hip extension on a round foam roll was greater than that on the floor ($p<.05$). These findings suggest that the unilateral hip-extension exercise on a round foam roll can be used to activate the lumbar multifidus and abdominal oblique muscles and causes a different increasing pattern between the two lifting sides.

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Introduction

Lumbar segmental stability is an important factor to treat low back pain (França et al, 2010; Freeman et al, 2010; Hides et al, 2001; Kumar, 2011). Rackwitz et al (2006) evaluated the effectiveness of lumbar segmental stabilizing exercise and demonstrated that it is more effective in reducing disability and pain than is medical management or general exercise for patients with acute or chronic low back pain (Moseley, 2002; O'Sullivan, 1997; Rackwitz et al, 2006).

Previous studies have recommended that specific exercise such as abdominal hollowing, one-arm or -leg lift in four-point kneeling, and side bridge should be considered to increase segmental stability (França et al, 2010; Hides et al, 1996; Kolber and Beekhuizen, 2007; Kumar, 2011). Danneel et al (2001) compared the effects of three types of stabilization training on the cross-sectional area of the lumbar multifidus (LM) muscle in patients with chronic low back pain. The stabilization training in the first group consisted of daily living activities that were intended to activate LM and maintain physiological

lordosis of the lumbar spine (Danneel et al, 2001). The same stabilization training was combined with an intensive lumbar extensor-strengthening program in the second and third group (Danneel et al, 2001). A back extensor-strengthening program consisted of one-leg extension in four-point kneeling and trunk lift or bilateral leg lifts to the greatest possible extension of hips and spine in the prone position (Danneel et al, 2001). The second group performed concentric and eccentric extension of the leg or trunk (dynamic-resistance training) (Danneel et al, 2001). The third group performed a 5-second static contraction between concentric and eccentric extension (dynamic-static resistance training) (Danneel et al, 2001). The results demonstrated that the dynamic-static resistance training was the most effective exercise to increase the cross-sectional area of LM muscle (Danneel et al, 2001). Excessive and repeated lumbar extension has a risk of low back pain and degenerative disk disease (Bennett et al, 2006; Harvey and Tanner, 1991; Watkins, 2002). For example, elite-level female gymnasts who perform repeated vigorous lumbar hyperextension often have degenerative disk disease (Bennett et al, 2006).

An unstable surface has been used to challenge exercise difficulty and increase muscle strength. Previous studies have demonstrated that abdominal muscle activity is increased on an unstable compared with stable surface (Imai et al, 2010; Kim et al, 2011). In contrast, Drake et al (2006) have shown that multifidus muscle activity is not significantly increased by back extension, contralateral arm and leg lift, and leg raise on a Swiss ball (unstable surface). A round foam roll is an unstable surface. Previous research has shown that the unilateral hip flexion performed on a round foam roll results in greater abdominal muscle activation than does the same exercise performed on a stable surface in the supine position (Kim et al, 2011). Unilateral hip flexion on a round foam roll causes rotation, so the abdominal muscle contracts to maintain balance in neutral position. We thought that unilateral hip ex-

tension on a round foam roll would challenge abdominal and back muscle activities similarly without excessive lumbar extension. However, no study has investigated whether unilateral prone hip extension exercise on an unstable foam roll can effectively activate the LM and abdominal oblique muscles. Therefore, the purpose of this study was to compare the activity of the LM, external oblique (EO), and internal oblique (IO) muscles during unilateral prone hip extension on the floor and on a round foam roll.

Methods

Participants

Fifteen healthy volunteers were recruited for this study (10 men, 5 women). All participants were free of low back pain, previous lumbar injury or surgery, spinal deformity, or neuromuscular or joint diseases in the lumbar area and lower extremities for 6 months prior to the enrollment. Ely's test, which requires that the participant's hip remain stationary until 120°, was negative for all participants. If the pelvis rises from the table during active knee flexion in a prone position, this is regarded as a positive sign of rectus femoris stiffness (Peeler and Anderson, 2008). Participant who had any regular training programs involving the back and abdominal muscles within the previous 3 months were excluded. All participants had right leg dominance, which was determined by kicking a soccer ball (Hoffman et al, 1998; Jacobs et al, 2005). The mean age, height, and weight of the participants are summarized in Table 1. Prior to the study, the principal investigator explained all the procedures in detail to the participants and obtained their written informed consent.

Instruments

Surface electromyography (EMG)

EMG data of bilateral EO, IO and LM muscles were collected using a Noraxon TeleMyo 2400 sys-

Table 1. General characteristics of subjects (N=15)

Characteristics	Mean±SD	
	Male (n=10)	Female (n=5)
Age (yrs)	26.1±4.5	21.6±.9
Height (cm)	175.7±5.8	159.0±5.3
Weight (kg)	71.4±9.0	51.0±4.3

tem¹⁾ and analyzed using Noraxon MyoResearch 1.16 XP software. The skin was shaved and then swabbed with alcohol-soaked cotton before electrode placement to minimize skin resistance. Surface electrodes were attached at an interelectrode distance of 2 cm. LM electrodes were placed 3 cm lateral to the spinous process at L5 (Colado et al, 2011; Hibbs et al, 2011). EO and IO electrodes were placed at the midpoint between the anterior-superior iliac spine (ASIS) and the ribs and at the midpoint between the anterior superior iliac crest and the symphysis pubis and proximal to the inguinal ligament, respectively (Cram et al, 1998; Cynn, 2010). The raw EMG signal was recorded at a sampling rate of 1000 Hz. A bandpass filter of 20~450 Hz was used to eliminate movement artifacts. The EMG signal was processed to the root mean square (RMS) using a window of 50 milliseconds. For normalization, the RMS of a 5-second maximal voluntary isometric contraction (MVIC) was measured three times for each muscle,

as recommended by Dankaerts et al (2004). The average RMS of three measurements was used to determine the MVIC of each muscle.

Procedures

Each participant was instructed to lie prone on either the floor or a round foam roll²⁾ (15.2×91.4 cm). The two supporting surfaces were randomized by balloting number 1 for the floor and number 2 for the round foam roll. To avoid contact between the electrodes and the floor, two tables were arranged with a gap between them that ran from just above the umbilicus to below ASIS under the floor condition. A target bar was placed so that the participant's thigh touched it at 10° extension of the hip joint with full extension of the knee joint (Figure 1 and 2). Participants attempted to keep their spines neutral on both supported surfaces during unilateral hip extension, and they were instructed to sustain the isometric contraction for 5 seconds. EMG data were collected when the participant maintained the test position without loss of balance and without lumbar rotation. Each participant completed three trials on the floor and three on the round foam roll. The average of each set of three trials was used for data analysis.



Figure 1. Right-hip extension on the floor.



Figure 2. Right-hip extension on a round foam roll.

Statistical Analysis

A paired t-test was used to compare muscle activity during hip extension performed on the floor and on the round foam roll, with the level of significance set at $\alpha=0.05$. Statistical analysis was performed using PASW Statistics version 18.0 software.

1) Noraxon TeleMyo 2400T, Noraxon Inc., Scottsdale, AZ, U.S.A.

2) Foam Therapy Rolls, Sammons Preston Rolyan, Bolingbrook, IL, U.S.A.

Results

Bilateral LM, EO and IO muscle activity was greater on the round foam roll compared with that on the floor during left-hip extension (Table 2)($p < .05$). During right-hip extension, muscle activity of the right EO, left IO and bilateral LM muscle was greater on the round foam roll compared with that on the floor (Table 3)($p < .05$).

Discussion

We compared the muscle activity during unilateral hip extension on the floor and on a round foam roll. Previous research has revealed that the instability, relatively small contact area, and reduced somatosensory input of a round foam roll require greater muscle activity to maintain lumbar stability (Kim et al, 2011). The results of the current study showed

that the muscle activity on a round foam roll was greater than on the floor.

EO and IO activity depended on lifting-leg side. During right-hip extension, ipsilateral EO and contralateral IO activity was significantly increased. This result is consistent with previous studies, which found that ipsilateral EO and contralateral IO activity were greater during right-leg extension in the four-point kneeling (Stevens et al, 2007) and supine positions (Kim et al, 2011). Janda has indicated that trunk muscle slings are necessary for facilitating reciprocal gait patterns between the upper and lower extremity as well as for rotational trunk stabilization (Page et al, 2009). The spiral sling is one of the anterior trunk muscle slings, and the opposite sides of the EO and IO create a spiral sling and maintain trunk stability (Page et al, 2009). Therefore, the right (ipsilateral) EO and left (contralateral) IO increased during right-hip extension to counter rotational movement on the round foam roll.

Table 2. Comparison of muscle activity during left hip extension (%MVIC)

Muscle	Floor		Foam roll		t	p
	Mean±SD ^a	95% CI ^b	Mean±SD	95% CI		
Left EO ^c	8.63±5.22	6.14~11.29	14.23±8.97	9.84~18.80	-4.16	<.05
Right EO	6.82±4.24	4.76~9.12	14.22±10.54	9.70~20.00	-3.45	<.05
Left IO ^d	8.43±5.45	5.96~11.18	17.52±15.74	11.07~25.93	-2.76	<.05
Right IO	8.17±4.78	5.90~10.44	16.48±12.91	10.76~23.31	-2.74	<.05
Left LM ^e	27.25±10.22	22.52~32.60	43.20±14.69	36.17~50.34	-4.68	<.05
Right LM	27.09±7.98	23.05~31.09	44.39±19.36	35.52~54.95	-4.59	<.05

^astandard deviation, ^bconfidence interval, ^cexternal oblique, ^dinternal oblique, ^elumbar multifidus.

Table 3. Comparison of muscle activity during right hip extension (%MVIC)

Muscle	Floor		Foam roll		t	p
	Mean±SD ^a	95% CI ^b	Mean±SD	95% CI		
Left EO ^c	10.02±8.55	6.36~14.46	12.98±8.92	8.79~17.36	-1.41	>.05
Right EO	7.10±4.06	5.14~9.20	14.88±8.78	11.04~19.71	-4.41	<.05
Left IO ^d	8.95±6.35	6.12~12.12	16.86±14.76	10.84~25.05	-2.50	<.05
Right IO	10.03±8.07	6.61~14.50	15.96±14.49	9.82~23.94	-1.55	>.05
left LM ^e	29.42±11.63	23.78~35.36	42.96±16.44	34.95~51.52	-3.82	<.05
Right LM	26.41±7.98	22.33~30.16	43.14±18.62	34.60~52.97	-4.67	<.05

^astandard deviation, ^bconfidence interval, ^cexternal oblique, ^dinternal oblique, ^elumbar multifidus.

During left-hip extension, bilateral EO and IO activity was increased on the round foam roll compared with the floor. These results might be related to leg dominance. Sung and Kim (2011) reported that the spinal range of motion is significantly different depending on the dominant hip motion. They suggest that the decreased axial trunk range of motion with the dominant hip is related to stiffened passive structures of the hip joint. All participants in our study had right-leg dominance, and they were instructed to maintain a neutral spine position during hip movement, so more trunk rotation might be expected during left-hip extension. Additionally, the round foam roll was unstable and created rotation when participants lifted the leg (Kim et al, 2011). The trunk muscles on the round foam roll were challenged more during left-hip than right-hip extension. Thus, bilateral muscles were co-contracted to maintain trunk stability. This was consistent with previous findings demonstrating that the activity of all the abdominal muscles was greater on a round foam roll than on the floor during non-dominant leg lifting. However, to establish the relationship between leg dominance and trunk muscle activity during hip extension, further study is needed on participants who have left-leg dominance because all participants had right-leg dominance in our study.

Participants performed unilateral hip extension without arm support in the prone position on the floor and on a round foam roll in our study. Compare with similar exercises in previous studies, LM muscle activity was approximately 20% MVIC during unilateral hip extension in four-point kneeling (Drake et al, 2006; Stevens et al, 2007) and approximately 60% MVIC during static lumbar extension with the trunk parallel to the floor and the pelvis supported by fixing the feet on the table (Colado et al, 2011). Drake et al (2006) suggested that the use of an exercise ball does not increase the challenge imposed on the musculoskeletal system of healthy young participants because abdominal and back mus-

cle activity is unchanged or decreased on the ball during unilateral hip extension in four-point kneeling and static lumbar extension compared with the same maneuver on a mat (floor). Our results demonstrated that LM activity was approximately 27% MVIC on the floor and 43% MVIC on the round foam roll (Table 2 and 3). The round foam roll created a greater challenge for the LM muscle. Although LM activity on the round foam roll was less than that with static lumbar extension on the floor, the exercise on a round foam roll had the advantage of preventing excessive lumbar extension during exercise. This result could be used to prescribe a gradual exercise protocol clinically.

This study had some limitations. First, we used surface electrodes to collect LM activity data. Stokes et al (2003) have recommended that accurate measurement of multifidus muscle activity requires intramuscular electrodes because surface electrodes placed over multifidus muscles are more sensitive to the adjacent longissimus muscles. We aimed to minimize crosstalk of adjacent muscles by collecting LM activity data at the L5 level. Second, our study involved healthy young participants, so the results cannot be generalized to other populations. Therefore, further studies should investigate symptomatic subjects and the general population.

Conclusion

Unilateral hip extension on a round foam roll caused greater muscle recruitment than the same exercise on the floor. A difference in muscle activity was noted between the two side during lifting, LM, EO and IO muscle activity increased bilaterally during left-hip extension on a round foam roll, and bilateral LM, ipsilateral EO, and contralateral IO muscle activity increased during right-hip extension. These findings suggest that the unilateral hip extension exercise on a round foam roll can be used to activate the LM and abdominal oblique muscles.

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