An Analysis of Muscle Activities of Healthy Women during Pilates Exercises in a Prone Position

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Abstract. [Purpose] This study analyzed the activities of the back and hip muscles during Pilates exercises conducted in a prone position. [Subjects] The subjects were 18 healthy women volunteers who had practiced at a Pilates center for more than three months. [Methods] The subjects performed three Pilates exercises. To examine muscle activity during the exercises, 8-channel surface electromyography (Noraxon USA, Inc., Scottsdale, AZ) was used. The surface electrodes were attached to the bilateral latissimus dorsi muscle, multifidus muscle, gluteus maximus, and semitendinous muscle. Three Pilates back exercises were compared: (1) double leg kick (DLK), (2) swimming (SW), and (3) leg beat (LB). Electrical muscle activation was normalized to maximal voluntary isometric contraction. Repeated measures analysis of variance was performed to assess the differences in activation levels among the exercises. [Results] The activity of the multifidus muscle was significantly high for the SW (52.3±11.0, 50.9±9.8) and LB exercises(51.8±12.8, 48.3±13.9) and the activity of the semitendinosus muscle was higher for the LB exercise (49.2±8.7, 52.9±9.3) than for the DLK and SW exercises. [Conclusion] These results may provide basic material for when Pilates exercises are performed in a prone position and may be useful information on clinical Pilates for rehabilitation programs.
Key words: Back and hip muscles, Electromyography, Pilates

INTRODUCTION

The spine plays a crucial role in reducing the stress delivered to each segment when a person moves and balances the shearing forces that occur between spinal segments[1]. It has been reported that strengthening the upper and lower extremities enables efficient functioning of the lumbar region, and strengthening the lumbar region enables efficient functioning of the upper and lower extremities[2].

Lack of isometric lower back muscle endurance is a major risk factor for non-specific low back pain (LBP)[3]. A study that compared control subjects with patients with tired lumbar muscles and LBP verified that the ability to sense change was damaged in patients with LBP in the lumbar position[4].

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The Pilates method uses a ball or a mat in spine stabilization exercises and has recently been recognized as the best option for improving the stability of the spine as well as endurance and extension of the (abdominal and lumbar) trunk muscles[5]. Electromyographic analysis provides information about appropriate postures for exercises, and the relative quantity of muscle activity during the exercise. Using electromyography (EMG), Arokoski et al.[6] reported the effects of traditional lumbar stabilization exercises in the quadruped, prone, and standing positions. Some studies have used EMG to examine the activity of back muscles during Pilates exercise[7]. However, research analyzing back and hip muscle activity during Pilates exercises—(1) double leg kick (DLK), (2) swimming (SW), and (3) leg beat (LB)—in a prone position is lacking. This study used EMG activities to analyze the activities of the latissimus dorsi, multifidus, gluteus maximus, and semitendinosus muscles during three modified mat Pilates exercises (DLK, SW, and LB).

SUBJECTS AND METHODS

The subjects were 17 healthy women who had practiced

at a Pilates center for more than three months, who voluntarily participated in this experiment after being given a sufficient explanation about the purpose and method of this study (age: 29.25±4.73 years, weight: 52.25±3.77 kg, height: 162.38±5.58 cm, body mass index 19.82±1.2 kg/m^2). Individuals with known medical problems, histories of spinal or abdominal surgery, or episodes of back, shoulder, or hip pain requiring treatment that had occurred 6 months before this study were excluded. This study was approved by hospital and all participants provided their written informed consent.

All exercises were explained by a physical therapist who had experience as a Pilates instructor and has received training in the Pilates method.

To examine muscle activity during exercise, an 8-channel surface EMG equipment (Noraxon USA, Inc., Scottsdale, AZ) was used. The collected EMG analog signals were sent to a TeleMyo DTS system to convert them into digital signals. They were then filtered, and additional signal processing occurred using MyoResearch XP 1.07 software on a personal computer. The sampling rate of the EMG signals was 1000 Hz, and a 40 to 250 Hz bandpass filter and 60 Hz notch filter were used. To reduce the skin resistance of the EMG electrodes, hair on the area where the electrodes were to be attached was removed with a shaver, and the horny layer was removed by rubbing the area with sandpaper several times. The skin was sterilized with alcohol, and the electrodes were attached.

The electrodes were attached to a 2 cm area lateral from the lumbar 4–5 for the multifidus muscle, and 3 cm away from the scapula inferior angle on a line slanting at 24 degrees in the inferolateral direction for the latissimus dorsi muscle. Electrodes were also attached halfway between the sacral vertebra and the greater trochanter for the gluteus maximus, and halfway between the ischial tuberosity and the medial condyle of the tibia for the semitendinous muscle[8]. Each electrode pair was situated in parallel with the muscle fiber orientation at an inter-electrode distance of 2 cm, and one reference (ground) electrode was placed on the superior border of the right iliac crest.

Measurements were made in the same position as in the manual muscle test presented by Kendall et al[9]. To measure the maximum voluntary isometric contraction (MVIC) of the multifidus muscle, the subject's legs were fixed with both hands on the occiput, raising the trunk. To measure the gluteus maximus, the subject lay prone, and the experimenter fixed the pelvis of the subject. When the subject, who lay prone, extended the hip joint backward with the knee joint flexed at 90 degrees, maximum resistance was applied to the distal femoral area. To measure the activity of the semitendinosus muscle, the subject lay prone with the knee joint flexed at 70 degrees and maintained the same angle while the experimenter applied maximum resistance to the distal areas of the lower extremities. To measure the latissimus dorsi, the subjects lay prone with their arms flexed and the shoulder in internal rotation, and maximum resistance was applied to the forearms. Each MVIC test was conducted three times, for 5 sec each time. The average values of the muscle activities of the middle three seconds were used for normalization. The subjects rested for 2 minutes to prevent muscle fatigue.

Table 1. Mean ± SD normalized surface electromyography amplitudes (% MVIC) of each muscle tested during the three Pilates exercises

Muscle	Double leg kick	Swimming	Leg beat	
Rt latissimus dorsi	36.2±10.9	45.8±8.6	39.8±13.3	*
Lt latissimus dorsi	32.4±9.8	42.7±12.4	37.2±15.7	*
Rt multifidus	38.5±12.5	52.3±11.0	51.8±12.8	*
Lt multifidus	37.1±11.9	50.9±9.8	48.3±13.9	*
Rt gluteus maximus	22.1±10.5	31.3±10.7	31.7±14.0	*
Lt gluteus maximus	20.5±10.4	30.0±8.7	32.7±13.5	*
Rt semitendinosus	33.6±6.9	39.2±6.7	49.2±8.8	*
Lt semitendinosus	32.4±7.7	37.8±8.1	52.9±9.3	*

*Significant difference ($p<0.05$). Unit: % MVIC

The subjects learned how to perform the three motion types of Pilates exercises via a video and instruction for about 10 min. The double leg kick alternates flexion and extension of the legs, kicking the heel toward the buttock for two pulses and then switching legs. For the SW exercise, the subjects assumed a prone position, with arms extended overhead and lifted the trunk and legs while executing the exercise. For the leg beat exercise, the subjects lay prone, raised both legs, breathed in five times and out five times, and knocked their big toes together. To prevent the equipment from being touched by the hands during exercise, subjects placed their hands on their waists and held them there without any movement. When the subjects knocked their big toes together, they extended their legs gradually. Those who did dynamic movements simultaneously raising their legs and arms during concentric back extension (e.g., extending the spine) were excluded. The EMG signal data were recorded simultaneously during the two sets.

Each muscle activity of each Pilates exercise was analyzed using repeated measured analysis of variance. Post hoc analyses were performed, when necessary, using the paired t test. All statistical analyses were performed with SPSS statistical software (version 19; SPSS Inc, Chicago, IL) with a statistical significance. level of α=0.05

RESULTS

The MVIC% activity levels ranged from 20.46% to 52.30% during the three Pilates exercises (Table 1). Muscle activity of the right latissimus dorsi, was higher during SW exercise than during the DLK ($p<0.09$) and LB ($p<0.013$) exercises. Muscle activity of the left latissimus dorsi, was higher during the SW exercise than the DLK and LB ($p<0.07$) exercises. Muscle activities of the bilateral multifidus muscles, were significantly higher during the SW and LB exercises than during the DLK exercise ($p<0.000$). Muscle activities of the bilateral gluteus maximus, were significantly lower during the DLK exercise than during the SW and LB exercises (right: $p<0.003$, $p<0.02$; left: $p<0.02$, $p<0.001$). Muscle activities of the bilateral semitendinosus, were highest during the LB exercise, followed by the SW exercise, and the DLK exercise (right: $p<0.001$, $p<0.000$, $p<0.000$; left: $p<0.009$, $p<0.000$, $p<0.000$).

DISCUSSION

The most interesting findings for the muscle activities that the activity of the multifidus muscle was significantly high in the SW and LB exercise, and the semitendinosus muscle activity was higher in the LB exercise than in the other motions.

The latissimus dorsi originating from the shoulder is a two-joint muscle that crosses between the glenohumeral joint and the scapula-thoracic joint. The muscle's strength is activated for the movement of the humerus and is aided by the scapula[10]. Although the latissimus dorsi engages in powerful adduction and extension of the shoulder, the muscle traverses the humerus from the posterior chest wall and therefore engages in lateral flexion and extension of the back[11]. Potvin et al.[12] reported that in a prone position trunk extension was accompanied by scapular movement. In this study as well, the activity of the latissimus dorsi with shoulder flexion movement was highest during the swimming exercise.

Previous researchers have reported that among 18 exercises in which the MVIC values of the multifidus muscle ranged from 5.0% to 71.9%, muscle activity was highest at 71.9±40.4% in a prone position[13]. Maryela et al.[7] noted that the activity of the multifidus muscle was highest during swimming exercises among the Pilates prone position exercises (swimming, double leg kick, and one leg kick). In this study, muscle activity was higher during the SW exercise than during the DLK exercise, and higher during the LB exercise than during the DLK exercise. Muscle activity during exercises probably is related to moment arm length and load. During the SW exercise that extends the upper and lower extremities alternatively within a range of minimal back lordosis. Accordingly, the lumbar torque load is located farther from the rotation of the axis along the moment arm[14], and the multifidus muscle is activated more to overcome the load of rotation. There was no difference in multifidus muscle activity between the LB exercise and SW exercises. Back muscle activity is possible by appropriately using the upper and lower extremities.

The moment arm of the gluteus maximus increases along with increase in the hip extension angle. However, the moment arm of the semitendinosus decreases as hip extension increases[15]. Lehman et al.[16] noted that the gluteus maximus was activated in the final moments of prone hip extension. Because of its the muscle moment arm, the gluteus maximus is relatively advantageous for generating strong power in hip extension positions. In this study, semitendinosus muscle activity was significantly higher than gluteus maximus activity during the SW and LB exercises that extend the knees and the legs. Semitendinosus muscle activity was particularly higher during the LB exercise than during the DLK and SW exercises, because the activity of the muscle likely increases while leg movements such as abduction and adduction are performed that do not exist in the other exercises. Given that the MVIC values of multifidus and semitendinosus muscle activities did not significantly differ, appropriate adjustment of the intensity of physical therapy that uses the lower extremities in a prone position is necessary.

Lumbar muscle activity using the moment arm of the upper and lower limbs when exercises were performed using all four extremities was highest, and therefore, intervention of appropriate load is necessary when subjects perform exercises. In addition, given that the difference in muscle activities of the multifidus and the semitendinosus during the LB exercise, that raises both legs, was not large, untrained subjects who do not use the appropriate breathing method who may anteriorly tilt the pelvis as a result, may place an excessive burden on their backs. Therefore, the study results may provide basic material for subjects who perform exercises.

The subjects of this study were limited to women who had practiced Pilates exercises for more than three months, and gradual development of exercise programs by comparing muscle activities between normal adults and patients with lumbar pain, who have not performed Pilates exercises, before and after three months of exercise is necessary.

REFERENCES

1) Wilke HJ, Wolf S, Claes LE, et al.: Stability increase of the lumbar spine with different muscle groups. A biomechanical in vitro study. Spine, 1995, 20: 192–198. [Medline] [CrossRef]
2) Arokoski JP, Valta T, Airaksinen O, et al.: Back and abdominal muscle function during stabilization exercises. Arch Phys Med Rehabil, 2001, 82: 1089–1098. [Medline] [CrossRef]
3) Demoulin C, Vanderthommen M, Duysens C, et al.: Spinal muscle evaluation using the Sorensen test: a critical appraisal of the literature. Joint Bone Spine, 2006, 73: 43–50. [Medline] [CrossRef]
4) Taimela S, Kankaanpää M, Luoto S: The effect of lumbar fatigue on the ability to sense a change in lumbar position. A controlled study. Spine, 1999, 24: 1322–1327. [Medline] [CrossRef]
5) Bernardo LM: The effectiveness of Pilates training in healthy adults: an appraisal of the research literature. J Bodyw Mov Ther, 2007, 11: 106–110. [CrossRef]
6) Arokoski JP, Kankaanpaa M, Valta T, et al.: Back and hip extensor muscle function during therapeutic exercises. Arch Phys Med Rehabil, 1999, 80: 842–850. [Medline] [CrossRef]
7) Menacho MO, Obara K, Conceição JS, et al.: Electromyographic effect of mat pilates exercise on the back muscle activity of healthy adult females. J Manipulative Physiol Ther, 2010, 33: 672–678. [Medline] [CrossRef]
8) Kendall FP, McCreary EK: Muscles, Testing and function; Baltimore: Williams and Wilkins, 1983, 6–230.
9) Kendall FP, Kendall McCreary E: Muscles, Testing and Function, 4th ed. Hagerstown: Lippincott Williams and Wilkins, 1993, 165–359.
10) Bogduk N: The morphology and biomechanics of latissimus dorsi. Clinical Biomechanics, 13, 1098, 377–385.
11) Guzik DC, Keller TS, Szpalski M, et al.: A biomechanical model of the lumbar spine during upright isometric flexion, extension, and lateral bending. Spine, 1996, 21: 427–433. [Medline] [CrossRef]
12) Potvin JR, McGill SM, Norman RW: Trunk muscle and lumbar ligament contributions to dynamic lifts with varying degrees of fexion. Spine, 1991, 16: 1099–1107. [Medline] [CrossRef]
13) Arokoski JP, Valta T, Kankaanpaa M, et al.: Activation of lumbar paraspinal and abdominal muscles during therapeutic exercises in chronic low back pain patients. Arch Phys Med Rehabil, 2004, 85: 823–832. [Medline] [CrossRef]
14) Dolan P, Adams MA: The relationship between EMG. Activity and extensor moment generation in the erector spinae muscles during bending and lifting activities. J Biomech, 1993, 26: 513–522. [Medline] [CrossRef]
15) Pohtilla JF: Kinesiology of hip extension at selected angles of pelvifemoral extension. Arch Phys Med Rehabil, 1969, 50: 241–250. [Medline]
16) Lehman GJ, Lennon D, Tresidder B, et al.: Muscle recruitment patterns during the prone leg extension. BMC Musculoskelet Disord, 2004, 5: 3. [Medline] [CrossRef]