International Journal of Internet, Broadcasting and Communication Vol.16 No.1 156-162 (2024)
http://dx.doi.org/10.7236/IJIBC.2024.16.1.156

IJIBC 24-1-19

Effects of Angle of Foot-Bar and Knee Posture on Core Muscle Activity during Pilates Reformer High-Plank

Kihong Kim[1], Hanna Choi[2], Hwanjong Jeong[3]

[1]*Professor, Department of Sports and Health Care, Dankook University, Korea*
[2]*Master, Department of Sports and Health Care, Dankook University, Korea*
[3]*Visiting Professor, Department of Sports and Health Care, Dankook University, Korea*
[1]*Bodykim@dankook.ac.kr*
[2]hanna@naver.com
[3] *Juan88@dankook.ac.kr*

Abstract

The purpose of this study was to investigate the muscle activity of internal oblique, rectus femoris, and multifidus according to knee posture and foot bar angle during pilates reformer high flank exercise. Twelve women in their 20s were recruited within six months of their experience as pilates instructors. The subjects performed six types of high flanks according to knee posture and foot bar angle. EMG signals of internal oblique, rectus femoris, and multifidus during exercise were measured and analyzed by integral EMG. The collected data were processed by repeated measures two-way ANOVA. In this paper it shows the following results. First, internal oblique iEMG was not significantly different according to knee posture and foot bar angle. Second, the rectus femoris had an interaction effect according to knee posture and foot bar angle. Third, there was no significant difference in multifidus according to knee posture and foot bar angle. In conclusion, according to the exercise method, the activity of the rectus femoris was the highest in the knee bending and high foot-bar angle high plank exercise, and there was no difference between the internal oblique and multifidus.

Keywords: *Pilates, Reformer, Core muscle, High Plank, EMG*

1. Introduction

The core muscle is a complex of muscles that are located in the hip, lumbar and pelvis, and the stabilization exercise to train it requires a combination of function and nerve control that contributes to the stability of the trunk [1]. Pilates, a typical exercise for core stabilization, is designed to be functional, easy,

Manuscript Received: December. 26, 2023 / Revised: January. 16, 2024 / Accepted: January. 27, 2024
Corresponding Author: ssilverman@naver.com
Tel:***-****-****
Visiting Professor, Department of Sports and Health Care, Dankook University, Korea

and safe to use movements using human joints using specific tools or devices [2]. Pilates can improve the central stability, muscular strength, and flexibility of the body by training the abdomen [3]. The middle-aged women who received Pilates training reported that their ability to mobilize deep abdominal muscles and stability around the pelvis increased compared to the group without training [4].

There is a high plank as a pilates action to stabilize the core muscles [5-7]. The high flank is a form of a prone bridge posture that can be adjusted in the form of quadruped knees, stretching and knee lifting, and leg lifting in the form of a typical core exercise that stretches arms and legs [8,9].

One of the instruments used in pilates, the reformer is a pilates exercise that can be performed using springs and pulleys, and it is possible to exercise the strength and flexibility of the whole body. The pilates reformer tool exercise possibles with the various method while moving the location of foot-bar and carriage [10]. The pilates motion using the reformer is widely used because it has the advantage of being able to stand, sit, lie, open chain motion and closed chain motion in various resistance movements using hands and footrests caught in springs and pulleys.

However, the movements of pilates are not scientifically verified, and there is no study analyzing the movements using the apparatus. Therefore, this study analyzed the muscle activity during the exercise using the reformer apparatus to investigate the exercise effect according to the flank posture.

2. Experiment Materials and Methods

2.1 Subject

The subjects of this study were females in their 20s who lived in Cheonan-si, Chungcheongnam-do and had more than 6 months of Pilates instructor experience. The study was conducted with the final subjects fully explaining the purpose, and procedures of the study and fully notifying the expected benefits and inherent risks and inconveniences of participating in this experiment. Table 1 is shown the characteristics of the research subjects.

Table 1. Characteristics of subjects

Subjects	Age(yr)	Weight(kg)	Height(cm)	Career(month)
N=9	21.00±1.33	56.00±9.49	160.80±5.39	47.60±16.24

2.2 Experimental Procedure

Before conducting the study, a preliminary briefing on the experimental method and measurement method was conducted to the surveyor and the research subjects. After completing the recruitment of the subjects, the measurement order for each posture was determined through random cross-allocation for the reliability of the measurement. The high flank motion of this study was performed in six ways according to foot-bar angle and knee posture. The electromyograms of multifidus, internal oblique, and rectus femoris were measured during the high-plank exercise for each posture, and they were converted into integral electromyography (iEMG) and analyzed.

2.3 High Plank Exercise

For the high flank motion, six methods were performed for 10 seconds according to three foot-bar angles

(20°, 53°, 70°) and two knee postures (knee extension, knee bending). In order to minimize the error between movements due to physical exhaustion, we took a rest for 3 minutes between each movement. Table 2 is shown the the specific appearance of the high flank motion.

Table 2. Lower Extremity Elevation Reformer High Plank Exercise

	20°	53°	70°
Knee Extension			
Knee Flexion			

2.4 EMG Measurement

To measure the EMG signal, a wired 4-channel EMG (Laxha, Korea) was used. Two surface electrodes were attached to the area 1 cm apart from the insertion site of the intramuscular electrode, and the wire connected to the electrode was fixed to prevent noise. EMG measurements were measured for 10 seconds from the beginning of the exercise, and raw data for 6 seconds except for 2 seconds before the start and 2 seconds before the end were used for data processing. Rectus femoris was attached to the midpoint between the anterior inferior iliac spine (AIIS) and the patella. The internal oblique was attached 2 cm below the medial direction of the anterior superior iliac spine (ASIS) and at the lateral 2 cm point. The multifidus was attached to the posterior superior iliac spine (PSIS) at a lateral 2 cm distance from the lumbar spine 5 spinous process. The measured EMG signal was converted to integral EMG.

2.5 Statistical Analysis

In this study, IBM SPSS statistics (ver 22.0) statistical program was used to calculate the mean and standard deviation of the variables. Repeated measures two-way ANOVA according to foot bar angle and knee posture were analyzed by Bonferoni method, and the significance level was set at α=.05.

3. Result

3.1 Differences in Internal Oblique integral EMG

The iEMG of internal oblique did not significant difference according to foot bar angle, and there was no difference in knee posture. There was no interaction effect according to foot bar angle and knee posture. Table 4 is shown the difference of oblique iEMG according to foot-bar angle and knee posture during lower extremity elevation high-plank exercise.

Table 3. Difference of Internal Oblique iEMG according to Foot-bar Angle and Knee Posture during Lower Extremity Elevation High-plank Exercise(μV)

Type	Knee extension	Knee flexion		F	*P*
20°	16.25±15.56	15.39±9.04	Foot-bar(F)	.433	.655
53°	14.17±11.59	13.37±7.94	Knee(K)	.069	.797
70°	14.21±8.82	14.19±11.14	(F) X (K)	.045	.956

M±SD

3.2 Differences in Rectus femoris integral EMG

There was a significant difference in rectus femoris iEMG according to foot bar angle (p=.018). Foot bar angle was 53° higher than 20° and 70° higher than 53° in both knee flexion and knee flexion postures. There was no significant difference according to the knee posture. There was an interaction effect according to foot bar angle and knee posture posture during lower extremity elevation high-plank exercise. Table 4 is shown the difference of internal oblique iEMG according to foot-bar angle and knee posture during lower extremity elevation high-plank exercise.

Table 4. Difference of Rectus Femoris iEMG according to Foot-bar Angle and Knee Posture during Lower Extremity Elevation High-plank Exercise(μV)

Type	Knee extension	Knee flexion		F	*P*
20°	13.17±3.99[#]	20.07±5.45[∬]	Foot-bar(F)	8.063	.018
53°	12.20±3.92[#]	22.94±8.60[∬]	Knee(K)	3.069	.069
70°	11.56±3.53[#]	27.04±13.67[∬]	(F) X (K)	34.550	.000

M±SD,

[∬]Knee flexion condition is significantly higher. [#]20°condition is significantly higher than other angles

3.3 Differences in Multifidus integral EMG

The iEMG of multifidus did not significant difference according to foot bar angle, and there was no difference in knee posture. There was no interaction effect according to foot bar angle and knee posture. Table 5 is show The Difference of multifidus iEMG according to foot-bar angle and knee posture during lower extremity elevation high-plank exercise.

Table 5. Difference of Multifidus iEMG according to Foot-bar Angle and Knee Posture during Lower Extremity Elevation High-plank Exercise(μV)

Type	Knee extension	Knee flexion		F	*P*
20°	7.12±9.06	7.10±5.08	Foot-bar(F)	8.33	.449
53°	10.03±10.20	7.39±3.44	Knee(K)	.277	.619
70°	10.26±11.66	9.22±10.69	(F) X (K)	.216	.808

M±SD

4. Discussion

In this study, the iEMG according to the angle of the high flank was different only in the rectus femoris. The rectus femoris is attached to the AIIS, patella and tibial tuberosity of the pelvis, and is a muscle that acts on the extension of the knee joint and the bending of the hip joint [11]. In this study, knee bending conditions were set to perform knee and hip joints at 90°, unlike normal high flank, and the subjects were encouraged to maintain 90°. In other words, the posture of the high flank and the knee bending high flank conducted in this study shows a difference in the angle of the knee joint and the hip joint.

The iEMG reflects the amount of motor units mobilized as an indicator of muscle activity [12].

Therefore, the difference of the iEMG of the rectus femoris according to the knee angle can be regarded as the muscle activity for the stability of the hip joint and the knee joint which are in the most unstable state of the exercise posture [13], and the activity of the rectus femoris to support the changing center of gravity is increased as the angle of the foot-bar increases. In previous studies, it was reported that the activity of the muscles controlling the pelvis and waist was increased in the form of raising the legs by putting the feet on the step box [14]. This can be explained by the fact that the lower the foot-bar angle, the higher the internal oblique activity, and the higher the multifidus activity, although there was no significant difference.

5. Conclusion

This study sought to determine the strength of core muscles following the corner of the foot bar and the corner of the tree during high plank exercise using Pilates reformer equipment. For this purpose, we explained six types of high plank movements with different angles of the corners of the foot bar and joints, and checked the movements during the exercise. Pain was measured in the rectus ribs, medial calvarius, and multifidus muscles and covered the following exercises.

In conclusion, as a result of analyzing muscle activity according to knee posture and foot bar angle during high flank exercise using pilates reformer equipment, it was confirmed that the activity of rectus femoris was the highest among knee bending and high foot-bar angle high flank exercise according to exercise method, and there was no difference between internal oblique and multifidus. On the other hand, the study failed to investigate more muscle activity due to a small number of subjects and limited EMG channels. It is necessary to conduct scientific verification of pilates movements for more diverse groups through follow-up studies.

References

[1] J. D. Willson, C. P. Dougherty, M. L. Ireland, I. M. Davis, "Core stability and its relationship to lower extremity function and injury," *JAAOS-Journal of the American Academy of Orthopaedic Surgeons*, Vol. 13, No. 5, pp. 316-325. Sep 2005.
DOI: https://doi.org/10.5435/00124635-200509000-00005

[2] J. Lee, S. J. Seo, "A Study of Middle Aged Women, on Their Muscle Activity and Subjective Analysis of The Body according to Pilates Positions," *J Kor Soc Dance Sci*, Vol. 33, No. 4, pp. 109-23, Oct 2016.

[3] N. J. Kim, H. W. Moon, B. H. Lee, "Effects if Pilates Mat Exercise and Detraining on Body Composition and Blood Leptin Concentration in the Middle-aged Obese Women", *Journal of Korean Physical Education Association for Girls and Women*, Vol. 22, No. 1, pp. 1-13, March 2008.

[4] L. Herrington, R. Davies, "The influence of Pilates training on the ability to contract the transversus abdominis muscle in asymptomatic individuals," *Journal of bodywork and movement therapies*, Vol. 9, No. 1, pp. 52-57, Jan 2005.
DOI: https://doi.org/10.1016/j.jbmt.2003.12.005

[5] R. A. Ekstrom, R. A. Donatelli, K. C. Carp, "Electromyographic analysis of core trunk, hip, and thigh muscles during 9 rehabilitation exercises," *Journal of Orthopaedic & Sports Physical Therapy*, Vol. 37, No. 12, pp. 754-762, Dec 2007.
DOI: https://www.jospt.org/doi/10.2519/jospt.2007.2471

[6] D. Czaprowski, A. Afeltowicz, A. Gębicka, P. Pawlowska, A. Kędra, C. Barrios, M. Hadala, "Abdominal muscle EMG-activity during bridge exercises on stable and unstable surfaces," *Physical Therapy in Sport*, Vol. 15, No. 3, pp. 162-168. Aug 2014.
DOI: https://doi.org/10.1016/j.ptsp.2013.09.003

[7] R. L. Snarr, M. R. Esco, "Electromyographical comparison of plank variations performed with and without instability devices," *The Journal of Strength & Conditioning Research*, Vol. 28, No. 11, pp. 3298-3305, Nov 2014.
DOI: https://doi.org/10.1519/JSC.0000000000000521

[8] V . Akuthota, S. F. Nadler, "Core Strengthening," *Archives of Physical Medicine and Rehabilitation*, Vol. 85, No. 1, pp. 86-92, March 2004.
DOI: https://doi.org/10.1053/j.apmr.2003.12.005

[9] B. C. Queiroz, M. F. Cagliari, C. F. Amorim, I. C. Sacco, "Muscle activation during four Pilates core stability exercises in quadruped position," *Archives of physical medicine and rehabilitation*, Vol. 91, No. 1, pp. 86-92, Jan 2010.
DOI: https://doi.org/10.1016/j.apmr.2009.09.016

[10] M. Roller, A. Kachingwe, J. Beling, D. M. Ickes, A. Cabot, G. Shrier, "Pilates Reformer exercises for fall risk reduction in older adults: A randomized controlled trial," *Journal of bodywork and movement therapies*, Vol. 22, No. 4, pp. 983-998, Oct 2018.
DOI: https://doi.org/10.1016/j.jbmt.2017.09.004

[11] D. A. Neumann, Kinesiology of the musculoskeletal system: foundations for rehabilitation. Elsevier Health Sciences, 2016.

[12] K. H. Kim, H. J. Jeong, C. J. Hong, H. S. Kim, B. K. Kim, "Effect of Wearing a Thermal Compression Sleeve on Isokinetic Strength and Muscle Activity of Wrist Flexors and Extensors," *International Journal of Internet,* Broadcasting and Communication, Vol. 14, No. 2, pp. 183-191, May 2022.
DOI: https://doi.org/10.7236/IJIBC.2022.14.2.183

[13] J. M. Byrne, N. S. Bishop, A. M. Caines, K. A. Crane, A. M. Feaver, G. E. Pearcey, "Effect of using a suspension training system on muscle activation during the performance of a front plank exercise," *The Journal of Strength & Conditioning Research*, Vol. 28, No. 11, pp. 3049-3055, Nov 2014.
DOI: https://doi.org/10.1519/JSC.0000000000000510

[14] S. Y. Park, W. G. Yoo, "Effect of height of feet on trunk muscle activity and pelvic tilt angle during prone bridge exercises," *Isokinetics and Exercise Science*, Vol. 24, No. 3, pp. 189-194. Aug 2016.
DOI: https://doi.org/ 10.3233/IES-160616