A comparison of muscle activation and exertion level between plank exercise with and without suspension

Eui-han Jeong*, Jong-Hoon Moon**, Ho-jin Shin***, Hwi-young Cho****
*student; Dept. of Physical Therapy, Gachon University
**Professor; Dept. of Occupational Therapy, Kyungdong University
***Graduate student; Dept. of Health Science, Gachon University Graduate School
****Professor; Dept. of Physical Therapy, Gachon University
e-mail:hwiyoung@gachon.ac.kr

플랭크 운동을 하는 동안 서스펜션의 유무에 따른 근육 활성화와 운동 수준의 비교

정의한*, 문종훈**, 신호진***, 조휘영****
*가천대학교 물리치료학과 학생
**경동대학교 작업치료학과 교수
***가천대학교 보건과학대학 대학원생
****가천대학교 물리치료학과 교수

Abstract

Background/Objectives: Plank exercise is a training method that increases the stability of the core muscles and is commonly used in the field of rehabilitation. The purpose of this study was to investigate the effect of plank exercise with suspension (PS) on muscle activation and exertion level in healthy participants.

Methods/Statistical analysis: Twenty-four healthy adults participated in the present study. Surface electromyography measurements were conducted for two plank exercises: general plank (GP) and PS. The activities of the rectus abdominis (RA), erector spinae (ES), rectus femoris (RF), and gluteus maximus (GM) muscles of the right and left sides (eight muscles in total) were investigated. The visual analogue scale was used to compare the exertion levels for the two exercises. Paired t test was used to analyze difference on muscle activity and exertion level between exercise.

Findings: The activation of the RA and GM was significantly greater in PS than in GP ($p<.05$). RF activation was significantly greater in GP than in PS ($p<.05$). There was no significant difference in ES activation between the two exercises. The exertion levels also showed no significant difference between the two exercises.

Improvements/Applications: This study demonstrated that PS can more highly activate the RA and GM muscles without increasing the exertion level than can GP.

1. Introduction

Plank exercise is effective in improving the strength and endurance of the core muscles, which increases the stability of the lumbar spine[1]. This stability is known to be important in improving body movement during various activities[2]. Strengthening the core muscles is typically effective in preventing and treating back pain. Core strengthening through plank exercise can reduce the incidence of back injuries and improve exercise performance[3]. Because of these effects, plank exercise is widely used in clinical practice as an exercise method to strengthen the core muscles.

Suspension exercise is a method of training on an unstable surface by using straps hanging from the ceiling, and has a wide spectrum of application (from physically weak patients to athletes)[4]. The use of suspension also has the advantage of easily adjusting the intensity by simply changing the lever arm. Because of these advantages, many clinicians use suspension training as a therapeutic exercise for patients with musculoskeletal pain. Providing an unstable surface by using suspension stimulates the neuromuscular system to increase the simultaneous contraction of muscles, and at the same time enables sensory motor training[5]. Previous studies have shown that suspension exercise improves lumbar stabilization, joint mobility, and muscle endurance, thereby enhancing the function of the core and trunk muscles[6-11].

Previous studies on general plank (GP) and plank exercise with suspension (PS) have been reported[10, 11]. Bak et al. studied the changes in trunk muscle activity in participants who conducted PS in various postures[10]. Recently, studies on plank exercise have shown that the activity of trunk muscles is increased when modified plank exercise is performed on an unstable surface. These studies have shown that exercise on an unstable surface increases the trunk muscle activity; however, the studies did not focus on the activation of the knee and hip extensors.

Byrne et al. compared GP and various methods of PS in healthy adults. Their results showed that the rectus abdominis (RA) muscle showed stronger activation in PS than in GP[11]. However, their study did not focus on the activation of knee and hip extensors. In addition, the suspension exercise they used is very difficult to perform because of its high intensity. Patients with back pain are more likely to experience pain during high-intensity exercises. Recently, Kahlaee et al. reported that patients with chronic low back pain did not show a significant increase in hip extensor activity when performing hip extension in the prone position[12]. The authors suggested that when applying exercise to patients, the gluteus maximus (GM) muscle should be considered in addition to the core muscles. GM activation through exercise may increase the sacroiliac joint stability, which may prevent low back pain[13-15]. However, there has been no study on the effect of PS focused on GM activation. In addition, previous studies did not compare the exertion level for the exercises. Considering that the exercise effects are associated with the exertion level[16], the exertion level should also be assessed to identify the effect of PS in improving muscle activity.

Therefore, the aim of this study was to investigate the effect of PS on the activation of the RA, erector spinae (ES), and knee and hip extensor muscles, and on the exertion level in healthy adults.

2. Methods

2.1 Subject

Twenty-four healthy adults were recruited. The inclusion criteria were as follows: body mass index between 18.5 and 25 kg/m2, no neurological pathology, no history of shoulder or spine surgery, and no cardiorespiratory disease. The exclusion criteria were as follows: psychological problems or inability to maintain the plank position.

2.2 Intervention

All participants were instructed on how to perform each plank exercise and allowed to practice for 5 min. After the practice, the next experiment was carried out after a 10-min rest period. For the GP, the participant was asked to hold the fist with the other hand and to keep both forearms in contact with the ground. The distance between the elbows was kept at 30 cm. The two feet were in contact with a stable ground. The research supervisor instructed the participants to perform scapular protraction and to maintain an angle of 90㈜. Drawing of the gluteal and abdominal muscles was performed to increase the tension of the gluteus and the abdomen. The height of the shoulders and hip from the ground was 25 cm. All participants were instructed to perform regular breathing during the plank exercises[18].

A suspension exercise device (Redcord AS, Staubo, Norway) was used for the PS. The height of the suspension was set to be equivalent to the length from the head to the heel of the participants. A narrow sling was applied to support the surface of both knees. The ankles were placed in a comfortable position. The height of the shoulders, hip, knees, and ankles from the ground was 25 cm. For the measurement of muscle activity, the two exercises were repeated five times for 30 s, with an interval between exercises of 1 min. To prevent fatigue between GP and PS, all participants were allowed a 10-min break after each exercise. The order of the exercises was counterbalanced.

2.3 Measurement

Before the experiment, to minimize the noise caused by impedance, hair on the skin surface was removed with a razor, and the skin was rubbed five times with sandpaper to remove the keratin and then cleaned with alcohol-soaked cotton balls. Electrodes were attached to each of the eight muscles in total (one to the right side and one to the left side of the RA, ES, rectus femoris [RF], and GM). The electrode attachment sites for each muscle were as follows[17]: for the RA, between the umbilicus and pubis to the middle of the muscle belly; for the ES, above and below the L1, midway of the muscle belly; for the RF, approximately half of the distance between the knee and the anterior superior iliac spine at center of the anterior portion of the thigh; and for the GM, parallel to the orientation of the midpoint of the superior muscle fibers between the second sacral vertebra and the greater trochanter. After attaching the electrodes, surface electromyography (Noraxon, Scottsdale, AZ, USA) was used to set the sampling rate to 3072 Hz. To set the frequency of the muscle to be tested, the band pass filter was set to 10–450 Hz, and filtering and root mean square processing were performed.

3. Results

3.1 General characteristics

The general characteristics of the participants are presented in Table 1.

[Table 1] General characteristics

Variables	Participants (n = 24)
Sex (men / women)[a]	15 / 9
Age (years)[b]	23.96 ± 2.79
Height (cm)[b]	168.58 ± 7.56
Weight (kg)[b]	60.04 ± 9.58
BMI[b]	20.96 ± 1.77

Values are expressed as the number of participants[a]ormean±SD[b].
BMI, body mass index

3.2 Muscle activity

RA and GM activity was significantly greater in PS than in GP ($p<.05$), whereas RF activation was significantly lower in PS ($p<.05$). ES activation was not significantly different between the two exercises (Table 2). There was no significant difference between the right and left muscles in the two exercises (RA: GP ($p=.607$), PS ($p=.430$); ES: GP ($p=.202$), PS ($p=.556$); RF: GP ($p=.607$), PS ($p=.430$); and GM: GP ($p=.796$), PS ($p=.348$)) (Table 2).

[Table 2] Comparison of core muscle activation during plank exercises

variables		General Plank	Plank using sling	t	p
		Mean ± SD	Mean ± SD		
Right	RA (MVIC %)	33.88 ± 15.05	52.38 ± 20.08	-6.666	.000***
	ES (MVIC %)	5.50 ± 2.02	6.08 ± 3.14	-.962	.346
	RF (MVIC %)	21.30 ± 7.57	12.33 ± 6.20	7.398	.000***
	GM (MVIC %)	19.10 ± 12.70	23.87 ± 9.99	-3.067	.008**
Left	RA (MVIC %)	33.57 ± 14.30	51.90 ± 19.19	-6.593	.000***
	ES (MVIC %)	5.63 ± 2.30	6.09 ± 2.46	-1.190	.246
	RF (MVIC %)	21.00 ± 7.85	11.86 ± 7.43	7.242	.000***
	GM (MVIC %)	18.89 ± 13.98	22.47 ± 11.00	-2.715	.016*

MVIC, Maximal voluntary isometric contraction; RA, Rectus abdominis; ES, Erector spinae; RF, Rectus femoris; GM, Gluteus maximus

4. Conclusion

The current investigation was conducted to compare the muscle activity and exertion levels between PS and GP. Our results showed that the exertion level was similar between the two exercises, and that PS resulted in stronger activity of the RA and GM than did GP. These findings suggest that PS can be a more effective exercise method than GP.

References

[1] Akuthota V, Ferreiro A, Moore T, Fredericson M. Core stability exercise principles. Curr Sports Med Rep, 2008;7(1):39-44.

[2] Cosio-Lima LM, Reynolds KL, Winter C, Paolone V, Jones MT. Effects of physioball and conventional floor exercises on early phase adaptations in back and abdominal core stability and balance in women. J Strength Cond Res. 2003;17(4):721-725. doi:10.1519/1533-4287(2003)017.

[3] Hall L, Tsao H, MacDonald D, Coppieters M, Hodges PW. Immediate effects of co-contraction training on motor control of the trunk muscles in people with recurrent low back pain. J Electromyogr Kinesiol. 2009;19(5):763-773. doi:10.1016/j.jelekin.2007.09.008.

[4] Kang H, Jung J, Yu J. Comparison of trunk muscle activity during bridging exercises using a sling in patients with low back pain. J Sports Sci Med. 2012;11(3):510-515. Published 2012 Sep 1.

[5] Verbunt JA, Seelen HA, Vlaeyen JW, van de Heijden GJ, Heuts PH, Pons K et al. Disuse and deconditioning in chronic low back pain: concepts and hypotheses on contributing mechanisms. Eur J Pain. 2003;7(1):9-21. doi:10.1016/s1090-3801(02)00071-x.

[6] Stray-Pedersen JI, Magnussen R, Kuffel E, Seiler S, Katch F. Sling exercise training improves balance, kicking velocity and torso stabilization strength in elite soccer players. Med Sci Sports Exerc. 2006;38(5):S243.

[7] Vikne J, Oedegaard A, Laerum E, Ihlebaek C, Kirkesola G. A randomized study of new sling exercise treatment vs traditional physiotherapy for patients with chronic whiplash-associated disorders with unsettled compensation claims. J Rehabil Med. 2007;39(3):252-259. doi:10.2340/16501977-0049.

[8] Huang JS, Pietrosimone BG, Ingersoll CD, Weltman AL, Saliba SA. Sling exercise and traditional warm-up have similar effects on the velocity and accuracy of throwing. J Strength Cond Res. 2011;25(6):1673-1679. doi:10.1519/JSC.0b013e3181da7845.

[9] Mau-Moeller A, Behrens M, Finze S, Bruhn S, Bader R,

Mittelmeier W. The effect of continuous passive motion and sling exercise training on clinical and functional outcomes following total knee arthroplasty: a randomized active-controlled clinical study. Health Qual Life Outcomes. 2014;12:68. Published 2014 May 9. doi:10.1186/1477-7525-12-68.

[10] Bak J, Shim S, Cho M, Chung Y. The Effect of Plank Exercises with Hip Abduction Using Sling on Trunk Muscle Activation in Healthy Adults. J Korean Phys Ther. 2017; 29(3): 128-134. doi: https://doi.org/10.18857/jkpt.2017.29.3.128

[11] Byrne JM, Bishop NS, Caines AM, Crane KA, Feaver AM, Pearcey GE. Effect of using a suspension training system on muscle activation during the performance of a front plank exercise. J Strength Cond Res. 2014;28(11):3049-3055. doi:10.1519/JSC.0000000000000510.

[12] Kahlaee AH, Ghamkhar L, Arab AM. Effect of the abdominal hollowing and bracing maneuvers on activity pattern of the lumbopelvic muscles during prone hip extension in subjects with or without chronic low back pain: A preliminary study. J Manipulative Physiol Ther. 2017; 40(2): 106-117. doi:10.1016/j.jmpt.2016.10.009.

[13] Hossain M, Nokes LD. A model of dynamic sacro-iliac joint instability from malrecruitment of gluteus maximus and biceps femoris muscles resulting in low back pain. Med Hypotheses. 2005;65(2):278-281. doi:10.1016/j.mehy.2005.02.035.

[14] Schwarzer AC, Aprill CN, Bogduk N. The sacroiliac joint in chronic low back pain. Spine (Phila Pa 1976). 1995;20(1):31-37. doi:10.1097/00007632-199501000-00007.

[15] Bullock-Saxton JE, Janda V, Bullock MI. Reflex activation of gluteal muscles in walking. An approach to restoration of muscle function for patients with low-back pain. Spine (Phila Pa 1976). 1993;18(6):704-708.

[16] Nicolò A, Marcora SM, Sacchetti M. Respiratory frequency is strongly associated with perceived exertion during time trials of different duration. J Sports Sci. 2016;34(13):1199-1206. doi:10.1080/02640414.2015.1102315.

[17] Criswell E. Cram's introduction to surface electromyography. Jones & Bartlett Publishers. 2010. http://samples.jbpub.com/9780763732745/32745_fmxx_final pdf

[18] Tong TK, Wu S, Nie J. Sport-specific endurance plank test for evaluation of global core muscle function. Phys Ther Sport. 2014;15(1):58-63. doi:10.1016/j.ptsp.2013.03.003.

[19] Ries AL. Minimally clinically important difference for the UCSD Shortness of Breath Questionnaire, Borg scale, and visual analog scale. COPD: Journal of Chronic Obstructive Pulmonary Disease, 2005;2(1):105-110. doi:10.1081/copd-200050655.

[20] Mok NW, Yeung EW, Cho JC, Hui SC, Liu KC, Pang CH. Core muscle activity during suspension exercises. J Sci Med Sport. 2015;18(2):189-194. doi:10.1016/j.jsams.2014.01.002.

[21] Lee J, Jeong KH, Lee HA, Shin J, Choi J, Kang S et al. Comparison of three different surface plank exercises on core muscle activity. Phys Ther Rehabil Sci. 2016; 5 (1):29-33.

[22] Escamilla RF, Lewis C, Pecson A, Imamura R, Andrews JR. Muscle Activation Among Supine, Prone, and Side Position Exercises With and Without a Swiss Ball. Sports Health. 2016;8(4):372-379. doi:10.1177/1941738116653931.

[23] Cugliari G, Boccia G. Core Muscle Activation in Suspension Training Exercises. J Hum Kinet. 2017;56:61-71. Published 2017 Mar 15. doi:10.1515/hukin-2017-0023.