

Comparison of Abdominal Muscle Activity after Sling and Swiss-ball Exercises in Asymptomatic Adults

Myoung-Hee Lee, PT, PhD, Byung-Kon Kim, PT, PhD[†]

Department of Physical Therapy, Kyungsoo University

¹Department of Physical Therapy, Daegu Health College

Received: August 7, 2014 / Revised: August 12, 2014 / Accepted: August 20, 2014

© 2014 J Korean Soc Phys Med

| Abstract |

PURPOSE: The purpose of this study was to investigate any changes in abdominal muscle activity after curl-up and jack-knife exercise using a sling and swiss-ball.

METHODS: Sixteen asymptomatic subjects were randomly assigned into either a sling exercise group (SG) or swiss-ball exercise group (SBG). Subjects performed curl-up and jack-knife exercise using sling and swiss ball. Activity of abdominal muscles (rectus abdominis and external oblique) was assessed using surface electromyography (EMG) and normalized maximal voluntary isometric contraction (MVIC) before and after exercises. The significance of differences between the SG and the SBG was evaluated by analysis of covariance (ANCOVA).

RESULTS: There was an increase in activity of all abdominal muscles after the curl-up and jack-knife exercises for 6 weeks. However, there was not a significant difference between the SG and the SBG after curl-up exercise ($p > .05$). There was also not a significant difference between the SG and

the SBG after Jack-knife exercise ($p > .05$) except for the right external oblique muscle ($p < .05$).

CONCLUSION: Exercises on an unstable surface using a sling and swiss ball are effective ways of abdominal muscle exercise.

Key Words: Sling, Swiss ball, Abdominal muscles

I. Introduction

Decreased spine stability is one of the common causes of lower back pain (LBP) (McGill et al, 2003; Norris & Matthews, 2008), and patients with chronic LBP display a shift beyond joint movements strategies in comparison with healthy adults (Thomas et al., 2007). Many study results indicate that when patient with chronic LBP perform activities of daily living, their erector muscles and abdominal muscles show muscle activity patterns different from those of healthy adults (Thomas et al., 2007; Van Daele et al., 2010; Descarreaux et al., 2005; Silfies et al., 2009; van der Hulst et al., 2010). This can cause problems for the balance between the abdominal muscles and the trunk muscles, which contribute to the stability of the lower trunk and play important roles in postural control and movements. Spine stability is achieved by appropriate

[†]Corresponding Author : atlas0420@dsc.ac.kr

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/3.0>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

abdominal and trunk muscle activation and coordination (McGill et al., 2003).

Results from a previous study indicate that improved stability could relieve LBP (Hodges et al., 2003), and spinal exercises using an unstable surface, such as a swiss ball or wobble board, have been used (Vera-Garcia et al., 2000). Exercises using an unstable swiss ball are low impact, can be highly utilizable in a home exercise program, and can strongly stimulate the proprioceptors for improving the ability to maintain balance (Han et al., 2001; Kim & Han, 2011). In studies on LBP, these exercises were reported to be effective in reducing pain and strengthening abdominal and lumbar muscles (Choi et al., 2012; Marshall & Murphy, 2006).

Another method for improving spinal stability is sling exercises, which are more effective for sense-exercise training than exercises on a mat. Previous studies have shown that sling exercises improve muscle strength and proprioception of patients using a closed kinematic chain (Dannelly et al., 2011) and maximize the effects of exercises because the proprioceptors can be facilitated (Jang et al., 2010; Jang et al., 2005). Therefore, sling exercises are quite effective for patient with LBP and impaired proprioceptive senses, and they can be applied in acute phases because they are performed to offset body weight.

Although diverse studies on abdominal muscle exercises in association with spinal stability and trunk muscle balance have been conducted to solve the problem, few study results could present specific effects between unstable surface exercises. Therefore, in the present study, we investigated whether sling and swiss-ball exercises that can be applied to abdominal muscles were effective in muscle activation, and we compared differences in muscle activity among exercise methods.

II. SUBJECTS AND METHODS

1. Subjects

Sixteen asymptomatic male college students who listened to a detailed explanation about this study participated. The subjects were randomized to two experimental groups: a sling exercise group (SG) and a swiss-ball exercise group (SBG). No subjects from either group had done any professional exercises or had a history of musculoskeletal disease, and they were instructed not to do concentrated exercises during the experiment time. The general characteristics of the subjects in this study are shown in Table 1. The study's principal objective and all study procedures were explained to the subjects, and written informed consent was obtained before the study. This protocol was conducted in accordance with the ethical standards of the Declaration of Helsinki.

2. Procedures

1) Exercise methods

The subjects were randomized into two experimental groups of SG and SBG. The subjects were taught to perform the curl-up and jack-knife exercises under the guidance of the researcher (Fig 1, 2).

Each set of abdominal muscle exercises consisted of 3 sessions, and each session consisted of 5 repetitions. It took 9 seconds for the subject to perform once. For all exercises, a 10-second break was given between each time and a 2-minute break was given between each session.

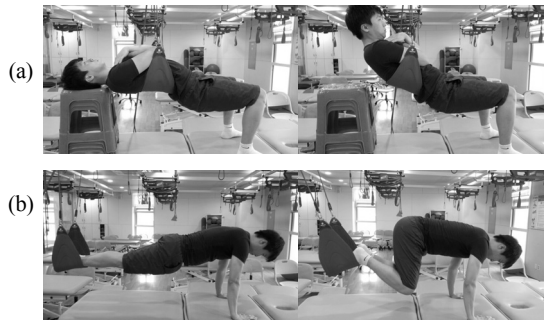


Fig 1. Sling exercise (a) curl-up (b) jack-knife

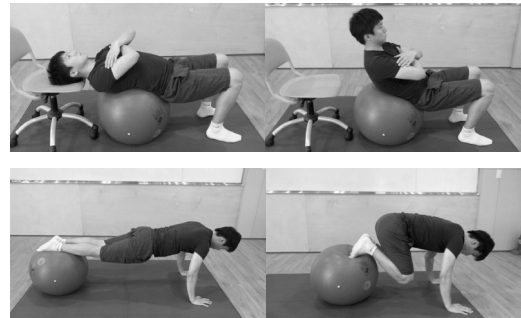


Fig 2. Swiss-ball exercise (a) curl-up (b) jack-knife

2) Measuring of surface electromyography

Surface electromyography (Myosystem 1200, Noraxon Inc., USA) was used to measure the muscle activity of abdominal muscles before and after exercise. The analog signals of the collected electromyography were sent to Myosystem 1200 and converted from analog to digital signals. They were filtered and other signals were processed with the software application Myoresearch XP 1.04 on a personal computer. The sampling rate of electromyography signals was set to 1,000 Hz (1,000 samples/sec) and the amplified waveforms were filtered to 20~500 Hz through band pass filtering. Artifacts were removed through a 60Hz notch filter and an ECG reduction filter. To quantify the electromyography signals collected from the target muscles during each exercise, the signals were analyzed by root mean square (RMS). To normalize the signals, the maximal voluntary isometric contraction (MVIC) of each muscle was measured for 7 seconds and the values of 3 seconds in the middle were averaged (% MVIC). To measure the MVIC of each muscle, verbal cues were given to ensure maximal effort, and each different isometric exercise against manual resistance was performed. Subjects performed maximal isometric contraction in three trials for 7 seconds before the experimental tasks. Fatigue was minimized by giving a 2-minute break after each contraction. The measurements for 3 seconds in the middle were averaged for normalization of the electromyography signals (% MVIC). Bipolar surface electrodes with a 3.0 mm radius

were attached to the muscle fiber running in the direction of the belly for each muscle. For measurement of the rectus abdominis, the electrodes were attached 1.5 cm to the left and right of the navel. The electrode sites on the body surface were shaved and cleaned with rubbing alcohol to reduce skin resistance.

3. Statistics

All values of muscle activity are expressed as mean and standard deviation. The significance of difference in abdominal muscle activity between the SG and the SBG was evaluated by analysis of covariance (ANCOVA). The level for statistical significance was defined as p-value less than .05.

III. Results

1. General characteristics of subjects

The demographic characteristics of the subjects are displayed in Table 1.

Table 1. General characteristics of subjects (mean±SD)

Group	Age (years)	Height (cm)	Weight (kg)
Sling group (n=8)	22.25±2.12	173.88±3.14	69.63±5.40
Swiss-ball group (n=8)	22.25±1.83	174.00±2.98	67.38±4.03

2. Comparison of abdominal muscle activity according to group

There was an increase in muscle activity of all abdominal muscles after curl-up and jack-knife exercises for 6 weeks. After curl-up exercise, activity of all abdominal muscles in the SBG was greater than in the SG. However, there was no significant difference between the groups ($p>.05$) (Table 2).

After Jack-knife exercise, activity of abdominal muscles also was not significantly different between the groups. However, activity of the right external oblique muscle in the SG was significantly greater than in the SBG ($p<.05$) (Table 2).

Table 2. Results of abdominal muscle activity according to group
(mean±SD)

Exercise	Muscle Group	Pre	Post	p	
Curl-up	LRA	SG	48.15±37.96	79.01±48.74	.97
		SBG	46.05±14.15	77.80±24.10	
	RRA	SG	52.97±25.88	92.38±20.78	.84
		SBG	42.14±20.24	85.30±18.25	
	LEO	SG	45.54±12.19	84.51±40.46	.64
		SBG	27.80±16.27	57.96±23.56	
	REO	SG	41.57±19.82	68.58±18.52	.57
		SBG	32.49±14.37	54.99±29.58	
Jack-knife	LRA	SG	27.85±7.83	75.86±34.31	.15
		SBG	31.13±9.39	53.31±27.80	
	RRA	SG	43.56±18.47	84.15±31.98	.30
		SBG	30.98±14.77	88.96±27.87	
	LEO	SG	60.98±20.88	86.84±28.81	.46
		SBG	38.16±17.02	55.55±29.42	
	REO	SG	45.81±19.61	73.69±24.41	.04*
		SBG	37.17±17.72	45.67±19.26	

LRA: left rectus abdominis, RRA: right rectus abdominis, LEO: left external oblique, REO: right external oblique, SG: sling exercise group, SEG: swiss ball exercise group
* $p<.05$

IV. Discussion

This study investigated the effect of the sling and swiss-ball on abdominal activity after curl-up and jack-knife exercises. There was an increase in activity of all abdominal muscles after the curl-up and jack-knife exercises, for 6 weeks. However, there was not a significant difference between the SG and the SBG after curl-up and jack-knife exercises except for the right external oblique muscle.

Many previous studies have confirmed that exercise on an unstable surface compared to a stable surface, such as the floor, is more effective for muscle training. Ha et al. (2014) suggested that performing the single-leg-hold exercises on form roll and a motorized rotating platform is more effective in increasing activity of abdominal muscles compared to on the floor. Another study showed that the swiss-ball exercise increased rectus abdominis activity more with the single-leg-hold and at the top of the press-up than off a swiss-ball (Marshall & Murphy, 2005). In addition, Kang et al. (2012) mentioned that the use of an unstable surface might increase the muscle activity of the trunk during bridging exercises.

Swiss-ball exercise and sling exercise are often performed on an unstable surface and are used to obtain stability for postural control. Previous studies on swiss-ball exercise found that stability training was effective and that exercise on an unstable surface was more effective than that on a stable surface (Duncan, 2009). Studies on the effects of stability training with the sling were also reported, such as a study that compared motor control exercise, sling exercise, and general exercise in chronic low back pain (LBP) patients (Dannelly et al., 2011). A study that compared sling and swiss-ball exercise effects in patients with LBP showed higher muscle activity of abdominal muscles with the sling than with the swiss-ball in curl-up and jack-knife exercises (Kang et al., 2012). When similar studies were performed, the sling exercise was more

effective than swiss-ball exercise. They said that the reason for higher muscle activity was moment arm length. If the body parts of subjects were located at the same height, the moment arm was longer when a sling rather than a swiss-ball was used, and this increased instability, resulting in higher participation of muscles.

The results of the present study show no difference between the sling and swiss-ball in curl-up and jack-knife exercises. These results are different from previous studies and it is presumed that this is due to the period of the exercises. This study has an important limitation: only the muscle activity of global muscles were studied because the local muscles could not be measured due to the nature of surface electromyography.

The abdominal muscle exercises to maintain trunk stability and balance are important in exercise programs for healthy adults and rehabilitation programs for patients. This exercise may focus on the effective period and specific muscle groups. Future work will focus on the specific effects of abdominal muscle training on various unstable surfaces and the effective period for strengthening of abdominal muscles.

V. Conclusion

In summary, this study demonstrates that exercise on an unstable surface using both a sling and swiss-ball are effective ways to exercise abdominal muscles exercise. When such evidence becomes sufficient, health programs for asymptomatic adults and rehabilitation programs for patients could be established more effectively, designed for their specific purposes.

References

Choi SH, Lim HY, Cho HY et al. The effects of trunk stabilization

exercise using swiss ball and core stabilization exercise on balance and gait in elderly women. *J Korean Soc Phys Med.* 2012;7(1):49-58.

Dannelly BD, Otey SC, Croy T et al. The effectiveness of traditional and sling exercise strength training in women. *J Strength Cond Res.* 2011;25(2):464-71.

Descarreaux M, Blouin J-S, Teasdale N. Repositioning accuracy and movement parameters in low back pain subjects and healthy control subjects. *Eur Spine J.* 2005; 14(2):185-91.

Duncan M. Muscle activity of the upper and lower rectus abdominis during exercises performed on and off a Swiss ball. *J Bodyw Mov Ther.* 2009;13(4):364-7.

Ha SM, Oh JS, Jeon IC, et al. The effects of surface condition on abdominal muscle activity during single-legged hold exercise. *J Electromyogr Kinesiol.* 2014; 64(14):142-4.

Han SW, Cho SY, Kim YS et al. The Effect of Isometric Exercise using Swiss Ball on the Flexibility, the Strength and the Waist and Hip Circumferences. *J Korean Soc Phys Ther.* 2001;13(1):73-82.

Hodges P, Kaigle Holm A, Holm S et al. Intervertebral stiffness of the spine is increased by evoked contraction of transversus abdominis and the diaphragm: in vivo porcine studies. *Spine.* 2003;28(23):2594-601.

Jang C, Choi HC, Bae SS. The Effect that cervical exercise has on joint range of motion a VDT syndrome patient. *J Korean Soc Phys Ther.* 2005;17(2):1-10

Jang KH, Choi JD, Lee MH et al. Comparison of modified sling exercise and general isometric exercise in patients with shoulder impingement syndrome. *J Korean Soc Phys Ther.* 2010;22(5):9-16.

Kang HK, Jung JH, Yo JH. Comparison of trunk muscle activity during bridging exercises using a sling in patients with low back pain. *J Sports Sci Med.* 2012;11:510-5.

Kim MH, Han SW. The influence of a core stability exercise program using swiss ball on muscle activity and pain in the lower back. *Journal of the Korean Academy*

- of Clinical Electrophysiology. 2011; 9(1):9-14.
- Marshall PW, Murphy BA. Evaluation of functional and neuromuscular changes after exercise rehabilitation for low back pain using a swiss ball: a pilot study. *J Manipulative Physiol Ther.* 2006;29(7):550-60.
- Marshall PW, Murphy BA. Core stability exercises on and off a Swiss ball. *Arch Phys Med Rehabil.* 2005; 86(2):242-9.
- McGill SM, Grenier S, Kavcic N, Cholewicki J. Coordination of muscle activity to assure stability of the lumbar spine. *J Electromyogr Kinesiol* 2003;13:353-9.
- Nadler SF, Malanga GA, Feinberg JH. Relationship between hip muscle imbalance and occurrence of low back pain in collegiate athletes: a prospective study. *Am J Phys Med Rehabil.* 2001;80(8):572-7.
- Norris C, Matthews M. The role of an integrated back stability program in patients with chronic low back pain. *Complement Ther Clin Pract* 2008;14:255-63.
- Silfies SP, Mehta R, Smith SS et al. Differences in feedforward trunk muscle activity in subgroups of patients with mechanical low back pain. *Arch Phys Med Rehabil.* 2009; 90(7):1159-69.
- Thomas JS, France CR, Sha D et al. The effect of chronic low back pain on trunk muscle activations in target reaching movements with various loads. *Spine.* 2007; 32(26):E801-8.
- Van Daele U, Hagman F, Truijen S et al. Decrease in postural sway and trunk stiffness during cognitive dual-task in nonspecific chronic low back pain patients, performance compared to healthy control subjects. *Spine.* 2010;35(5):583-9.
- Van der Hulst M, Vollenbroek-Hutten MM, Rietman JS et al. Lumbar and abdominal muscle activity during walking in subjects with chronic low back pain: support of the “guarding” hypothesis? *J Electromyogr Kinesiol.*2010;20(1):31-8.
- Vera-Garcia FJ, Grenier SG, McGill SM. Abdominal muscle response during curl-ups on both stable and labile surfaces. *Phys Ther* 2000;80(6):564-9.