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Original Article

Comparison of Abdominal Muscle Activity during Exercises Using a Sling and Swiss-ball

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Purpose: Spinal instability due to weakness of abdominal muscles is one of the major causes that induces low back pain (LBP). The purpose of this study was to investigate any differences in abdominal muscle activity during curl up, roll out, and jack knife exercises using a swiss-ball or sling.

Methods: Twenty healthy subjects were randomly assigned into either a swiss-ball exercise group (SBEG) or a sling exercise group (SEG). Subjects performed curl up, roll out and jack knife exercises using the swiss ball or sling. Activity of abdominal muscles (rectus abdominis and external oblique muscle) was assessed using surface EMG and normalized maximal voluntary isometric contraction (MVIC). The significance of differences between the sling exercise group and the swiss-ball exercise group was evaluated by the independent t-test.

Results: These Results indicated that activities of rectus abdominis on right and left of the SEG during the curl up exercise were significantly greater than the SBEG. During the roll out exercise, activity of the abdominal muscle was not significantly different between the SEG and SBEG. In addition, during the jack knife exercise, activities of the right rectus abdominis and left external oblique muscle in the SEG were significantly greater than the SBEG.

Conclusion: In conclusion, activity of the abdominal muscles was maximized when curl up and jack knife exercise were performed using the sling rather than the swiss-ball. Therefore, if increased activation of the abdominal muscle is the goal of an exercise program, curl up and jack knife exercises may be useful.

Keywords: Sling, Swiss ball, Abdominal muscle, EMG

Ⅰ. Introduction

Low–back pain is a major musculoskeletal disorder, and the cases of nonspecific low–back pain account for more than 85% of all cases of low–back pain.[1] In Korea, low–back pain affects up to 85% of the adult population and has a considerable healthcare cost. Patients with chronic low–back pain display a shift beyond the single joint movement strategy compared to healthy adults.[2]

This can cause balance problems between the abdominal muscles and the trunk muscles, which contribute to the stability of the lower trunk and play an important role in trunk postural control and movements. Numerous studies have shown that when chronic low–back pain patients perform functions, such as walking and sports, their erector spinae, rectus abdominis, and transeverse abdominis show muscle activity patterns different from those of healthy adults.[2–7]

A previous study demonstrated that activity induced in the diaphragm improved abdominal cavity pressure and spinal stability, and study results indicated that the improved stability could relieve low–back pain.[8] One of the most appropriate and effective methods for improving spinal stability is patients' active participation, and studies have shown that among diverse stability improving exercises, the sling exercise is more effective for sense exercise and

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low-back stability training than mat exercises. The sling exercise has been shown to improve strength and proprioception by using a closed kinematic chain,[9] and this stimulates the proprioceptor and maximizes the effect of the exercise.[10-13] Therefore, sling exercises offer an effective method for low-back pain patients with impaired proprioceptive senses and can be applied in acute phases because the sling exercise is performed to offset body weight.

Another exercise method for improving spinal stability is the Swiss ball exercise, which is highly applicable as part of a home exercise program, and is a low-impact exercise that minimizes impacts to the body.[14] Exercises on an unstable ball can stimulate the proprioceptor, thereby improving the ability to maintain balance and walk.[14,15] In studies on low-back pain patents, exercise using Swiss balls was reported to be effective for relieving pain and reinforcing lumbar and abdominal muscle strength.[16-18]

Previous studies have therefore demonstrated that patterns of activities in low-back pain patients are different from those seen in healthy persons. Although diverse studies on abdominal muscle exercises have been conducted to address this problem, most results could not demonstrate solid effects. Therefore, in the present study sling and swiss ball exercises that can be applied to low back pain patients have been applied to healthy persons and the differences in muscle activity among exercise methods compared. The results could be utilized as fundamentalbasic data to provide guides for the rehabilitation program of low back pain patients.

II. Methods

1. Subjects

Healthy 21 male college students who listened to detailed explanation about this study participated after signing a voluntary consent form. The subjects were randomized to two experimental groups of 10 members (sling exercise group: mean age±SD=20.18±1.33years, mean height ± SD=173.27 ± 4.43㎝, mean weight±SD=66.27±8.32kg) and 11 members (swiss ball exercise group: mean age ± SD=20.42 ± 1.56years, mean height±SD=175.67±6.47㎝, mean weight±SD=70.42±11.22kg). One member of the swiss ball group dropped out of this study during the experiment period for personal reasons. No subjects of either group had done any professional exercise or had a history of musculoskeletal disease, and they were instructed not to do intense exercise during the experiment period.

2. Experimental methods

1) Measurement

(1) Surface electromyography

Surface electromyography (Myosystem 1200, Norraxon Ins, AZ, USA) was used to measure the activities of rectus abdominis and external oblique muscle according to exercise method. The analog signals of the collected surface electromyography were sent to Myosystem 1200 and converted 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 1,000Hz (1,000 samples/second) and the amplified waveforms were filtered to 20~500Hz 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, they were analyzed by root mean square (RMS). To normalize them, 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 make sure maximal effort, and each different isometric exercises against manual resistance were performed. Subjects performed maximal isometric contraction in three trials for 7 seconds before the experimental tasks. Fatigue was minimized by giving a 2-min 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 3.0mm radius were attached in the muscle fiber running direction to the belly of each muscle. For measurement of rectus abdominis, the electrodes were attached to 1.5cm to the left and right of the navel. The body surfaces on which the electrodes were attached were shaved and rubbed with sandpaper and wiped with alcohol to reduce skin resistance.

(2) Exercise methods

The subjects performed exercise in the same way and the researcher measured the muscular activities of rectus abdominis muscle and external oblique muscle during exercise using sling and swiss ball (Figure 1,2).

(a)
(b)
(c)

Figure 1. Sling exercise (a) curl-up (b) roll-out (c) jack-knife.

(a)
(b)
(c)

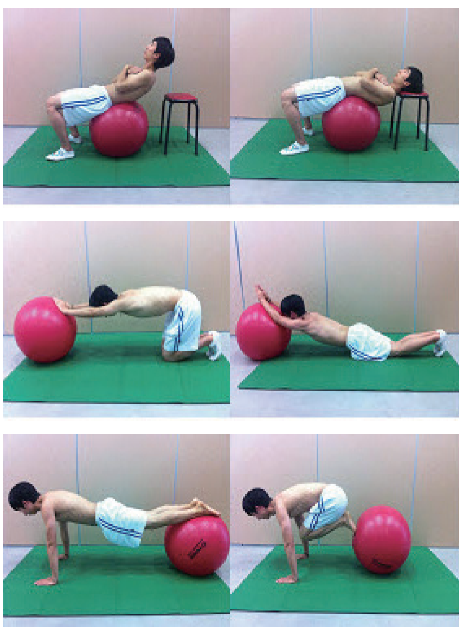

Figure 2. Swiss ball exercise (a) curl-up (b) roll-out (c) jack-knife.

The curl–up was performed lying supine with arms placed across the chest. Subjects were instructed to keep both feet on the floor and to position themselves so their low back was supported by sling or swiss ball with their trunk horizontally. Subjects were instructed to lift their head and shoulder towards the ceiling, to hold the position and then slowly return to the starting position.

The roll out was performed kneeling on the floor with hands and forearms on the sling or swiss ball. The subjects were instructed to roll the ball out a fully extended position (hip joint was fully extended), hold the position and then slowly return to the starting position.

The jack knife was performed with feet on the sling or swiss ball and hands on the ground (in a push–up position). With the trunk square to the ground, the knees are brought towards the chest. The legs are then extended back into the start position.

The sling exercise group and the swiss ball exercise group performed three types of abdominal muscle exercise. Each abdominal muscle exercise consisted of five sessions, each session lasted 9 seconds. For all exercises, a 10 seconds break was given between sessions and a 2 minutes break was given between exercises.

3. Statistical analysis

All values are expressed as mean and standard deviation (SD). Levene's test was used to assess the equality of variances in the two groups, and Levene's statistic was not significant ($p>0.05$), assuming equal variances between groups. The significance of the difference in abdominal muscle activities between the sling exercise group and the Swiss ball exercise group were evaluated by the independent t–test. The level for statistical significance was defined as a p value <0.05.

III. Results

Muscle activity of the rectus abdominis on right and left of the SEG were significantly greater than muscle activity of the SBEG during curl–up ($p<0.05$). But activity of the external oblique muscle was not significantly different between between SEG and SBEG. During roll out exercise, activity of abdominal muscle was not significantly different

Table 1. Results of abdominal muscle activity according to group (unit: %MVIC)

Exercise	Muscle	Swiss ball group	Sling group	p
Curl-up	LRA	31.06 ± 15.59	51.31 ± 24.43	0.040*
	RRA	40.16 ± 13.73	60.04 ± 23.03	0.031*
	LEO	28.09 ± 18.16	39.99 ± 16.77	0.146
	REO	33.31 ± 19.07	42.19 ± 13.66	0.247
Roll-out	LRA	44.22 ± 13.15	51.08 ± 35.55	0.574
	RRA	39.84 ± 18.71	61.91 ± 38.71	0.122
	LEO	31.78 ± 17.07	41.63 ± 13.90	0.174
	REO	32.13 ± 14.78	42.72 ± 19.32	0.186
Jack-knife	LRA	31.54 ± 8.81	36.66 ± 20.25	0.473
	RRA	30.78 ± 13.12	49.40 ± 23.95	0.045*
	LEO	40.35 ± 21.42	60.46 ± 18.70	0.038*
	REO	39.17 ± 17.99	46.32 ± 18.31	0.390

LRA: left rectus abdominis, RRA: right rectus abdominis, LEO: left external oblique, REO: right external oblique.
* p<0.05

between SEG and SBEG. And during jack knife exercise, activities of right rectus abdominis and left external oblique muscle in SEG were significantly greater than SBEG ($p<0.05$)(Table 1).

IV. Discussion

Previous studies have confirmed that low–back pain patients have different trunk muscle activity patterns compared to healthy adults. They showed a slower onset of trunk extensor muscles in target–reaching movements compared to healthy individuals,[2] and their paraspinal muscle activity and strength were decreased.[18] The thicknesses of their back muscles and transversus abdominis muscles differed from those of healthy adults,[19] and they also showed hip muscle imbalance.[20] Various studies using EMG and ultrasound have been conducted to confirm the improvement in stability, but systematic grounds for improved stability are still insufficient. Swiss ball and sling exercises are performed on an unstable surface and are used to obtain stability for postural control. Previous studies on the 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.[15,17,21] Furthermore, some studies reported that the curl–up exercise activated the upper rectus abdominis more than the lower rectus abdominis.[21,22] Studies on the effects of stability training with a sling have also been reported comparing motor control exercise, sling exercise, and general exercise in chronic low–back pain patients9 and comparing traditional and sling exercise strength in women.[23]

Results of the present study showed higher muscle activity in abdominal muscles with the sling compared to the Swiss ball with curl–up and jack knife exercises. This result is similar to the study by Kang et al. who showed that when low–back pain patients performed a bridging exercise, the sling exercise group showed significantly higher muscle activity compared to the floor and Swiss ball exercise groups.[23] When studies that used similar designs were examined, the sling exercise was more effective than the Swiss ball exercise. In particular, the sling exercise can induce the participation of local muscles.[23–25] In the present study, only the muscle activities of global muscles were studied because local muscles can not be measured due to the nature of surface electromyography. However, the activities of the rectus abdominis muscle and external obilique muscle, which are global muscles, were also higher in the sling exercise group because these muscles are used frequently during the curl–up and jack knife exercises. When the body parts of subjects were held at the same height, the arm was lengthened more when a sling was used compared to the Swiss ball, and this increased instability, resulting in higher muscle participation with the sling.Exercises may focus on specific muscle groups. In the future, the effect of stability training on various unstable surfaces should be objectively established, and muscle activity patterns of abdominal muscles or erect spinal muscles relative to the exercise method need to be comprehensively analyzed. As evidence of value is established, more effective exercise programs for healthy adults and rehabilitation programs for patients could be developed that correspond to the intended purpose.

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