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Original Article

Comparison of muscular activities in the abdomen and lower limbs while performing sit-up and leg-raise

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Abstact. [Purpose] This study compared the muscle activities of sit-up and leg-raise. [Subjects and Methods] The subjects of this study were healthy students in their 20s. For electromyography of sit-ups and leg-raises in the supine position, 5 muscle groups of the abdomen were selected for the attachment of sensors: the upper and lower rectus abdominis, external oblique, rectus femoris, and the iliopsoas. SPSS 20.0 was used for the statistical analysis. One-way ANOVA with repeated measures of all factors was performed to verify the statistical significance of the measurements taken for the muscle activities and follow-up verification was made with the Bonferroni post hoc test. [Results] Sit-up and leg raise showed a significant difference. The eccentric sit-up exercise elicited a significant increase in the activation of the abdominal muscle. The leg raise and eccentric sit-up exercises elicited significant increases in the activation of hip flexor muscle. [Conclusion] The eccentric sit-up had the most outstanding effect on the abdominal muscles involved in stability of the trunk.

Key words: Low back pain

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INTRODUCTION

The majority of people living in the modern era experience lumbar pain, and although there are numerous ways of reducing the pain, recent focus has been placed on the reinforcement of abdominal muscle strength through exercise therapy. Kim[1)] compared the contraction ability of the abdominal muscle between lumbar pain patients and normal people. The results showed that lumbar pain patients displayed a lower level of contraction ability in the abdominal muscles compared to normal people. Reinforcement of the abdominal muscles play an important role in the treatment and prevention of lumbar pain[2)]. The abdominal muscles are very important, since they assist the harmonious movement of the limbs and maintain the stability of the axis of the human body[3)].

Exercising the abdominal muscles is aimed not only at improving body control, but also at fortifying muscular endurance[4)]. Methods of reinforcing the abdominal muscles include sit-ups, straight leg-raises, etc. In addition, it is possible to effectively reinforce the abdominal muscles by using a diverse range of exercise equipment[5)]. Gurmaraes[5)] asserted that sit-ups fortify the upper rectus abdominis while straight leg-raises in the supine position target the lower rectus abdominis. In addition, Vera-Garcia et al.[6)] asserted that various abdominal muscles must be activated simultaneously, rather than a single abdominal muscle, in order to maintain stability of the body. However, there is inadequate research regarding the activation of the overall abdominal muscles when performing sit-ups and straight leg-raises in the supine position, and these are the most common exercises performed for strengthening the abdominal muscles.

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This study selected 2 representative methods of reinforcing the abdominal muscles, and measured and analyzed the extent to which the abdominal muscles were activated while performing these exercises.

SUBJECTS AND METHODS

Twenty healthy adult males and females attending D University were selected as the subjects of this study. The subjects were informed of the study purpose and methods, and they signed an informed consent form. Subjects recruited for this study had no neurological problems or musculoskeletal diseases. The subject characteristics were as follows (subject mean age: 20.5 yrs; 8 males, mean age: 20.5 yrs, mean height: 173.4 cm, mean weight: 65.3 kg; 12 females, mean height: 161.4 cm, mean weight: 53.4 kg).

For the electromyography of sit-ups and leg-raises in the supine position, 5 muscle groups of the abdomen were selected for the attachment of sensors: the upper and lower rectus abdominis, external oblique, rectus femoris, and iliopsoas[7]. For the upper and lower rectus abdominis, sensors were situated at the center of the abdomen above and below the navel separated by a gap of 3 cm. For the external oblique, sensors were attached in the direction of the grain of the muscular fiber between the right ribs and iliac crest, and along the median line of the armpit. For the rectus femoris, sensors were attached to the most protruding portion at the mid-point of the straight line that connects the ASIS and the central portion of the patella. For the iliopsoas, the sensor was attached to the medial aspect of the rectus femoris, inferior to the inguinal ligament.

After attaching the sensors for the electromyography, maximal voluntary isometric contraction (MVIC) was executed in the manual muscular strength test posture to obtain normalization values prior to the commencement of this experiment. Measurements of the MVIC values were made 3 times in each posture over a period of 5 seconds for each measurement. The 5-second electromyogram data converted to root mean square (RMS) values and the average strength of the electromyogram signal during the middle 3 seconds, excluding the first and the last second, was used as the 100% MVIC value in the analysis. A Telemyo 2400TG2 electromyogram (Noraxon USA, Inc. Scottsdale, AZ, USA) was used to record the electromyograms and the Myoresearch XP Master Edition from Noraxon was used for data analysis. A frequency of 1,500 Hz was used for the collection of the data.

The subjects were instructed to perform sit-ups and leg-raises in the supine position. A total of five measurements were made, with a period of rest of one minute between each measurement. For sit-ups, the knee joints were bent at an angle of 100°, with both hands crossed and placed on the chest while the ankles were held down. The concentric movement of lifting the trunk was performed for 3 seconds followed by the eccentric movement of lowering the trunk for 3 seconds. For the straight leg-raise in the supine position, both hands were placed next to the trunk and both shoulders were held down to prevent compensating action. The concentric movement of raising the legs was performed for 3 seconds followed by the eccentric movement of lowering the legs to the floor for 3 seconds. All experiments were approved by the Ethics Committee of Catholic University (CUPIRB-2015-012) of Pusan.

SPSS 20.0 was used for the statistical analysis. One-way ANOVA with repeated measures for all factors was performed to verify the statistical significance of differences in the upper and lower rectus abdominis, external oblique, rectus femoris and iliopsoas, and follow-up verification was made with the Bonferroni post hoc test.

RESULTS

The results of abdominal exercises were analyzed by repeated measure ANOVA and a significant difference in the interaction between abdominal exercise type and muscle activation ($p<0.05$) was found. The abdominal muscles displayed significant differences ($p<0.05$) between the exercises as illustrated in Table 1. The results of the follow-up verification are as follows.

Table 1. The comparison of muscle activation during exercises (%)

	SU	ESU	LR	ELR
URA	28.5±12.0[a)]	31.6±13.6[a)]	20.7±13.4[b)]	23.1±15.2[b)]
LRA	27.9±9.8[a)]	34.1±10.4[b)]	21.7±10.6[a)]	24.7±14.7[a)]
EO	23.1±9.5[a)]	27.6±11.0[a)]	14.5±9.0[b)]	15.7±10.7[b)]
I	13.2±7.4[a)]	15.8±8.0[b)]	17.6±8.1[b)]	18.5±10.4[b)]
RF	10.8±6.7[a)]	14.1±9.1[b)]	21.7±11.3[b)]	23.6±12.4[b)]

URA: upper rectus abdominis; LRA: lower rectus abdominis; EO: external oblique; I: iliopsoas; RF: rectus femoris; SU: sit-up; ESU: eccentric sit-up; LR: leg-raise; ELR: eccentric leg-raise

[a),b)]Different superscripts within the same columns indicate significant differences ($p<0.05$)

DISCUSSION

This study compared the muscular activities of the upper and lower rectus abdominis, the external oblique, iliopsoas, rectus femoris between sit-ups and leg-raises using electromyography, and also examine the differences in concentric and eccentric contractions.

Reinforcement of the abdominal muscles is a widely-used method for prevention and treatment of lumbar pain. In addition, actions of the abdominal muscle perform the role of stabilizing the lumbar region by increasing the intra-abdominal pressure and extending the thoracolumbar fascia. Therefore, reinforcement of the abdominal muscles is extremely important for reduction of lumbar pain[8].

Many lumbar pain patients display weakened abdominal muscle strength[9]. This study used electromyography in order to find the most effective exercise for reinforcement of the abdominal muscles. For the activation of the upper and lower rectus abdominis and the external oblique, the sit-up was found to be more effective than the straight leg-raise. However, for the activation of the iliopsoas and rectus femoris, the straight leg-raise was found to be more effective than the sit-up. On the basis of the present results of this study, it can be concluded that the sit-up is an exercise that facilitates activation of the abdominal muscles with low activation of the lower limb muscles.

In order to appropriately stabilize the trunk, it is necessary to optimally align the body between the pelvis and spine, and prevent excess movement of the pelvis as well as stress while the limbs are moving[10]. When engaging in the exercise of the abdominal muscles, it is not only the abdominal muscles that contract, but also the iliopsoas and rectus femoris, as they are attached to the trunk (spine and pelvic girdle). At the time of performing sit-ups, excessive contraction of the iliopsoas muscle or rectus femoris can damage the lumbar vertebrae[11]. In order to avoid this possibility, sit-ups must be performed using a trunk curl movement while reducing active hip flexion[11]. On the other hand, the straight leg-raise is deemed to be more appropriate for the reinforcement of the flexors since the activation of the flexors of the lower limbs is high while the activation of the abdominal muscles is low. Use of the flexors of the lower limbs should be avoided while exercising the abdominal muscles since it would aggravate the condition of patients with lumbar pain. According to the results of this study, the sit-up effectively reinforces the movement of the lower limbs on the stability of the trunk.

This study investigated the most effective abdominal exercise by measuring the muscular activities of the upper and lower rectus abdominis, external oblique, iliopsoas and rectus femoris. The eccentric sit-up had the most outstanding effect on abdominal muscles involved in the stability of the trunk.

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REFERENCES

1) Kim KH, Cho SH, Goo BO, et al.: Differences in transversus abdominis muscle function between chronic low back pain patients and healthy subjects at maximum expiration: measurement with real-time ultrasonography. J Phys Ther Sci, 2013, 25: 861–863. [Medline] [CrossRef]
2) McGill SM, Grenier S, Kavcic N, et al.: Coordination of muscle activity to assure stability of the lumbar spine. J Electromyogr Kinesiol, 2003, 13: 353–359. [Medline] [CrossRef]
3) Hodges PW, Richardson CA: Contraction of the abdominal muscles associated with movement of the lower limb. Phys Ther, 1997, 77: 132–142, discussion 142–144. [Medline]
4) Macedo LG, Latimer J, Maher CG, et al.: Motor control or graded activity exercises for chronic low back pain? A randomised controlled trial. BMC Musculoskelet Disord, 2008, 9: 65. [Medline] [CrossRef]
5) Guimaraes AC, Vaz MA, De Campos MI, et al.: The contribution of the rectus abdominis and rectus femoris in twelve selected abdominal exercises. An electromyographic study. J Sports Med Phys Fitness, 1991, 31: 222–230. [Medline]
6) Vera-Garcia FJ, Elvira JL, Brown SH, et al.: Effects of abdominal stabilization maneuvers on the control of spine motion and stability against sudden trunk perturbations. J Electromyogr Kinesiol, 2007, 17: 556–567. [Medline] [CrossRef]
7) Criswell E: Cram's introduction to surface electromyography. Jones & Bartlett Publishers, 2010, pp 348–363.
8) Akuthota V, Ferreiro A, Moore T, et al.: Core stability exercise principles. Curr Sports Med Rep, 2008, 7: 39–44. [Medline] [CrossRef]
9) Takemasa R, Yamamoto H, Tani T: Trunk muscle strength in and effect of trunk muscle exercises for patients with

chronic low back pain. The differences in patients with and without organic lumbar lesions. Spine, 1995, 20: 2522–2530. [Medline] [CrossRef]
10) Sahrmann S: Diagnosis and treatment of movement impairment syndromes. Elsevier Health Sciences, 2002, pp 32–34.
11) Norris CM: Abdominal muscle training in sport. Br J Sports Med, 1993, 27: 19–27. [Medline] [CrossRef]