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Original Article

Muscle activities of the rectus abdominis and rectus femoris and their ratio during leg raises performed by healthy adults

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Abstract. [Purpose] The purpose of this study was to analyze muscle activation during hip flexion in the supine position to examine the activation characteristics of the rectus abdominis and rectus femoris. [Subjects] The subjects of this study were 20 healthy adults (10 males and 10 females). [Methods] Muscle activities of the rectus abdominis and rectus femoris while raising the leg from 0°–60° were measured in 15-degree divisions and their ratio was calculated. [Results] Statistically significant differences were found in the muscle activities of the rectus femoris and rectus abdominis were found among each division of during hip flexion in the supine position. The rectus abdominis and rectus femoris ratios increased as the angle of hip flexion increased. [Conclusion] During hip flexion from 0°–45° in the supine position, femur motion caused hip flexion. At angles greater than or equal to 45° hip flexion was accompanied by pelvic motion.

Key words: Hip flexion, Leg raise, Muscle activities

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INTRODUCTION

The pelvis is an important body part that connects the trunk and the lower limbs, transferring the movement of the lower limbs to the trunk[1)]. The pelvis tilts anteriorly and posteriorly under the action of muscles during flexion and extension of the hip joint[2)]. Two major muscles that cause anterior and posterior tilting of the pelvis are the rectus abdominis and the rectus femoris. These two muscles secure the stability of the pelvis through coordination during hip joint flexion[1)]. For this reason, leg raises in the supine position are used as a trunk stabilization exercise to prevent unnecessary pelvic movements[3)].

Leg raises are achieved through coordinated action of the abdominal and leg muscles[4)]. This is why healthy adults perform leg raises to strengthen their abdominal muscles[5)]. Therefore, to increase activation of deep trunk muscles, various leg raising exercises are being studied by researchers[6)]. However, the relationship between muscles that directly interfere with anterior and posterior tilting of the pelvis to stabilize the position of the pelvis remains unclear at different angles during leg raises. Therefore, this study investigated the characteristics of the rectus abdominis and rectus femoris muscle that directly interfere with the anterior and posterior tilting of the pelvis during leg raises to clarify the relationship between leg and pelvic movement.

SUBJECTS AND METHODS

The subjects of this study were 20 helthy adults (10 males and 10 females). When selecting the participants, those with present or past malformation or neurological disease of the leg joints were excluded. All the subjects voluntarily participated in this study and signed an informed consent from, which stated that they could withdraw from the experiment at anytime of their choosing. The experimenter sufficiently explained the experimental procedures and dangers prior to the experiment. Moreover, this study complied with the ethical principles of the Declaration of Helsinki. The average age, height, and weight of the participants were 21.55±1.43 years old, 166.75±9.30 cm, and 57.7±10.63 kg, respectively.

In this study, an electromyography (EMG) system (Myosystem TM DTS, Noraxon Inc., USA) was used to measure muscle activation. For EMG signal processing, the MyoResearch XP master edition 1.06 program was employed. The sampling rate of EMG signals was set to 1,024 Hz, and data were filtered with a 20 to 500 Hz bandpass filter and a 60 Hz notch filter. The electrodes (IWC-DTS, 9113A-DTS) were Ag/AgCl electrodes with adhesive backing including hypoallergenic gel. The diameter of the conducting area was 1 cm and the distance between the electrodes was 2 cm. The electrode attachment sites were depilated with a razor, and horny substance was removed with sandpaper. The electrodes were attached after cleaning the attachment sites with an alcohol swab. The muscles selected around the hip were the rectus femoris and rectus abdominis. The activities of

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Table 1. Comparison of muscle activation and ratio in each division of the leg raise

	0°–15° division	15°–30° division	30°–45° division	45°–60° division
RF* (%RVC)	1,361.8±175.8	4,988.0±596.8†	6,031.9±617.2†	5,663.0±566.8†
RA* (%RVC)	192.3±40.1	567.1±120.2†	789.8±174.6†	1,159.1±268.6‡
Ratio of RA/RF* (%)	13.1±5.6	12.3±3.8	13.1±3.4	20.4±5.7†

RF: Rectus Femoris; RA: Rectus Abdominis; Ratio of RA/RF: RA/RF×100
Each value represents the mean ± SE. The values with different superscripts (†, ‡) in the same column are significantly different ($p<0.05$) according to Tukey's test.

each muscle were measured for five seconds in the anatomical position and converted to root mean square value. The level of muscle activation during exercise was expressed as % RVC, relative to the average muscle contraction (100%) in the middle one second of a three-second measurement; i.e. ignoring the first and last second of the measurement.

For precision of the raise, an arch with a radius adjusted to the leg length of each participant was created using a plastic rope, and the subjects raised their legs following the plastic arch from 0° to 60° of hip flexion.

The measured data were analyzed using one-way ANOVA to investigate the effect of leg raise angle on muscle activity. Statistical analyses were performed using SPSS ver. 17.0, and p values less than 0.05 were considered significant for all cases.

RESULTS

Statistically significant differences in the muscle activities of the rectus femoris and rectus abdominis were found among each division of the leg raise ($p <0.05$) (Table 1). The ratio of the rectus abdominis and rectus femoris increased as the angle of hip flexion increased ($p <0.05$) (Table 1).

DISCUSSION

This study was conducted to determine the characteristics of the muscles around the pelvis during the performance of leg raises. It was found that rectus abdominis activity increased more sharply than rectus femoris activity 45°–60° of a leg raise. This seems to be the result of posterior tilting of the pelvis to secure space between the pelvis and the femur for hip flexion during leg raises. Thus, the rectus femoris is used more during 0°–45° hip flexion, to induce anterior tilting and hip flexion of the pelvis, whereas rectus abdominis activation is used for hip flexion at 45° and greater, to induce hip flexion accompanied by posterior tilting of the pelvis. Therefore, lumbo-pelvic rhythm through the motion of the lower limbs starts to occur when the hip joint is in flexion of 45° or greater. This result supports previous studies, which have reported that movements of the femur and pelvis are related to the two joint muscles. Since the leg raise of the present study was performed by healthy adults without hamstring muscle shortening, it explains normal kinematics, not the influence of hamstring muscle tension. In terms of kinematics, it was shown that raising the leg to greater than or equal to 45° induces pelvic motion in normal adults. Patients with spinal disc herniation feel pain when raising the leg to greater than or equal to 45° because force is transferred to the lumbar spine. Researchers suspect a herniated intervertebral disc when the angle is greater than or equal to 60° during the straight leg raise test[7, 8]. This indicates direct movement of the pelvis in the 45°–60° range. The results of the present study confirm the results of research about the positive range of the existing SLR test.

It seems necessary to conduct further studies about the motions of the femur, pelvis, and lumbar spine to clarify the rhythms that occur in the human body.

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