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Research Article

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The Effects of Trunk and Lower Extremity Muscle Activation on Straight Leg Rising by Various Ankle Joint Rotation Angle

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| Abstract |

PURPOSE: This study intends to examine the effects of change of anatomical position of the ankle joint in open kinematic chain, an appropriate position for selective muscle training, on vastus lateralis obliques, rectus femoris, vastus medilais obliques, and rectus abdominalis muscle activation and to present an effective method of muscle training for patients and normal people.

METHODS: The participants of this study were Korean healthy adult in their 20s. The 8 channel surface electromyography was used to measure muscle activation while the subjects raised their legs under each condition. Under each condition, while the subjects raised the leg to hip joint flexion at 60° along the arch.

RESULTS: The analysis result of muscle activation by each section and position during leg rising. There were significant differences.

CONCLUSION: For independent strengthening of each muscle, muscle activation was measured according to leg raising angles and the result differed according to each section and position. If this study result is applied to muscle training for patients who need selective muscle training, more effective muscle strengthening will be made possible.

Key Words: Ankle joint rotation, Leg rising, Muscle activation

Ⅰ. Introduction

The lower extremities have the function of balance and weight bearing, and weight shifting control during gait. Patients who have disability in such function of the lower extremities have imbalance in the anterior, posterior, lateral and medial, left and right sides, which results in asymmetrical posture (de Haart, et al., 2005).

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The patients with knee extensor muscle weakness and those with knee pain, various training methods have been studied for the strengthening of the vastus medialis oblique and vastus lateralis oblique muscles. From a kinesiological viewpoint, open kinematic chain and closed kinematic chain is a representative movement on body. The distinction between open kinematic chain and closed kinematic chain lies in difference in their standard of movement (Prentice, 1999). In closed kinematic chain, eccentric contraction is predominant and shearing force is weak, having a merit of providing stability of the joints (Iwasaki, et al., 2006). Hung and Gross(1999) noted that vastus medialis obliques contraction and vastus lateralis oblique muscle activation were compared according to different ankle joint rotation angles (foot positions) directly related to the quadriceps muscle and there were no significant differences according to the three positions of the feet. This result means that closed kinematic chain was inadequate as a selective muscle strengthening method. Moreover, closed kinematic chain has a defect of providing excessive load on the knee joints and triggers imbalance muscle contraction during initial stage treatment of patients with muscle imbalance caused by pain and paralysis, aggravating symptoms (Neumann, 2002).

On the other hand, open kinematic chain is an exercise where the proximal part is fixed and the distal part moves freely; concentric contraction is preponderant and the occurrence of distraction force and rotation force is higher than in closed kinematic chain. Open kinematic chain also enables selective activation of muscles and has an advantage of being able to selectively adjust the amount of load on the knees (Neumann, 2002). In a study that compared vastus medialis oblique and vastus lateralis oblique muscle activation during knee joint extensor muscle strengthening exercise in open kinematic chain using Cybex among various muscle training methods of the lower limb muscles, knee joint extension accompanying hip joint adduction more activated the vastus medialis oblique muscle than extension in a neutral position(Hanten & Schulthies, 1990).

Accordingly, this study intends to examine the effects of change of anatomical position of the hip joint in open kinematic chain, an appropriate position for selective muscle training, on vastus lateralis obliques, rectus femoris, vastus medilais obliques, and rectus abdominalis muscle activation and to present an effective method of muscle training for patients and normal people.

Ⅱ. METHODS

The participants of this study were Korean college students in their 20s (male: 10, female: 10). When selecting the participants, those with malformation or neurological disease in the lower limb joints in the past or at the present time were excluded. All the subjects voluntarily participated in this study and signed an agreement on this experiment that contained that they were able to reject participation anytime if they wanted. The experimenter sufficiently explained experimental procedures and cautions prior to the experiment. As for general characteristics of participants, their average age, height, and weight was 21.55±1.43 years old, 166.75±9.30 cm, and 57.7±10.63 kg.

In this study, 8 channel surface electromyography (EMG) system (Myosystem TM DTS, Noraxon Inc., USA) was used to measure muscle activation while the subjects raised their legs under each condition : ankle joint rotation angle 30°, 0°, -30° (Fig. 1). For EMG signal processing, MyoResearch XP master edition 1.06 program was employed. The sampling extraction rate of EMG signals was set at 1024Hz and filtering was made at 20 to 500H using a Band pass filer and 60Hz notch filter was utilized. The electrodes (IWC-DTS, 9113A-DTS) were Ag/AgCl electrodes with adhesive strength including hypoallergenic gel and the diameter of conductivity area was 1cm and the distance between the electrodes was 2cm. Depilation

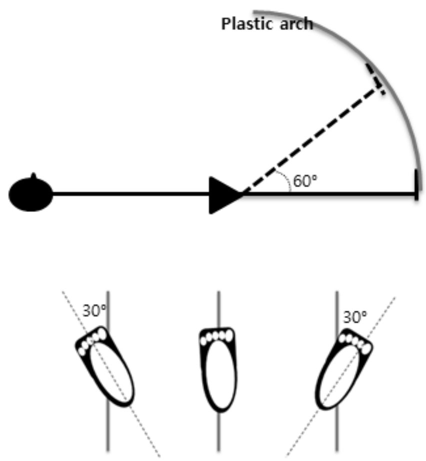

Fig 1. Methods of this study

was performed by a razor on the attaching sites; the horny substance was removed with sandpaper. The electrodes were attached after cleaning the sites with an alcohol swab to gather accurate electromyogram data. The selected muscles around the hip were the vastus lateralis oblique(about proximal 10cm lateral of thigh from the superior of the patellar), vastus medialis oblique(about proximal 8cm from the superior medial side of the patellar), rectus femoris(the superior of the patellar and middle of ASIS) and rectus abdominalis(about proximal 3cm from inferior lateral side of umbilicus). The root mean square data of each muscle was measured for five seconds in the anatomical position. The level of muscle activation during exercise was expressed as % RVC by calculating the relative muscle contraction of the 100% average muscle contraction in the middle one second of a 3 measurement; i.e. by ignoring the first and last second of the measurement.

For precise leg rising exercise, an arch with a radius suitable for the leg length of participants using a plastic pope was made and the leg was raised along the plastic arch. While the subjects raised the lower limb along the plastic arch, the ankle joint was fixed using a plastic toehold in order to maintain the rotation angle of the ankle joint.

Muscle activation data were ensemble averaged for each condition across the 3 trials. The measured data were analyzed using one-way ANOVA to investigate the effect of muscle activation on the each condition and leg rising angle. The statistical analyses were performed using SPSS ver. 17.0 and p-value less than 0.05 were considered significant for all cases.

Ⅲ. Results

According to the analysis result of lower limb muscle and abdominal muscle activation in leg raising according to ankle joint rotation angles, there were significant differences in the vastus lateralis obliquus at internal deviation, neutral position, and lateral deviation ($p<.05$). As for the rectus femoris, there was no statistically significant difference between differing positions at internal deviation, neutral position, and lateral deviation. Regarding the vastus medilais obliquus, there was significant difference between differing positions ($p<.05$). With regard to the rectus abdominalis, there was significant difference between differing positions (Table 1)($p<.05$).

Ⅳ. Discussion

Particularly, for normal function of the knee joints, balance of the vastus medialis and vastus lateralis muscles is very important (Stevens, et al., 2010). Most previous studies have looked at contribution degree of muscles that passed the quadriceps muscle and knee joints for the strengthening of the lower limb muscles and examined knee extension, weight bearing terminal knee extension, step exercise, and semi-squat as desirable exercise methods for the balance of the quadriceps muscle (Libingston, 1998).

This study concerned 20 students (male: 10, female:10) who conducted straight leg raising at a unit of 0° to hip joint flexion at 60° and measured and compared trunk and lower limb muscle activation at different ankle positions

Table 1. EMG activation of the trunk and quadriceps muscle by the rotation angle of ankle joint
(unit : %RVC)

	internal deviation	neutral position	lateral deviation	F	p
VLO	855.33±80.20	974.29±109.25†	644.79±70.42	3.58	.034*
RF	2912.31±245.98	3359.75±295.18	3360.76±274.71	.89	.413
VMO	888.41±83.42†	644.87±44.25	766.53±65.12	3.38	.041*
RA	503.82±67.91†	331.85±39.88	337.13±39.56	3.69	.031*

mean±SE, $p<0.05$
VLO : vastus lateralis obliques, RF : rectus femoris, VMO : vastus medilais obliques, RA : rectus abdominalis

(internal deviation, neutral deviation, and lateral deviation).

According to analysis result of trunk and lower limb muscle activation during straight leg rising at a posture that changed anatomical position of the hip joint using ankle rotation angles, there was significant difference at hip joint flexion at 0 to 60° in the vastus lateralis muscle, in particular, the most muscle activation in a neutral position.

This is considered because while during internal rotation the vastus medialis oblique muscle most contracts in order to maintain its posture and the rectus femoris most contracts in anatomical location for the stability of the hip joint, while the vastus lateralis oblique muscle most contracts in the middle location, in other words, in a neutral position.

The rectus femoris muscle did not have statistically significant differences under internal deviation, neutral deviation, and lateral deviation conditions at 0 to 60° of hip flexion, but muscle activation values were high at all hip joint flexion angles. This is regarded because the rectus femoris muscle as multi joint muscle engages in flexion of the hip joint and knee joint extension and therefore has high muscle activation level during straight leg raising exercise. The vastus medialis oblique muscle showed significant differences at hip joint flexion at 0 to 60° and muscle activation was highest in an internal deviation position. This is considered because internal rotation is opposite to stable location of the hip joint and foot is toward the medial direction and Q angle increases, making burden on the vastus medialis oblique muscle heavier (Newsam & Baker, 2004). The rectus abdominis muscle showed significant differences at hip joint flexion at 0 to 60° and muscle activation was highest in an internal deviation position. This is because the rectus abdominis muscle should act for pelvic posterior tilting in order to neutralize strong pelvic anterior tilting with hip joint flexor muscles. If sufficient stabilization by the rectus abdominalis muscle is not provided, contraction of the hip joint flexor muscles by pelvic anterior tilting is insufficient (Neumann, 2002).

Future research should aim to maintain muscle strength and balance in quadriceps muscle weakness patients through exercise of a single muscle and apply exercise to quadriceps muscle weakness patients and compare them with normal people.

Ⅴ. Conclusion

For independent strengthening of each muscle, muscle activation was measured according to leg raising angles and the result differed according to each section and position. If this study result is applied to muscle training for patients who need selective muscle training, more effective muscle strengthening will be made possible.

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