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The Effects of Isometric Extension at Different Knee Angles on Vastus Medialis Electromyographic Activity in Patients with Knee Joint Osteoarthritis

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Abstract. [Purpose] The objective of the study was to examine maximum voluntary isometric contraction (MVIC) of the vastus medialis at different knee angles in a knee joint isometric extension exercise for the knee joint osteoarthritis patients, and to identify the most effective extension angle for strengthening the vastus medialis. [Subjects] The subjects of this study were 17 knee joint osteoarthritis patients. [Methods] In order for the knee joint to be fixed at a certain angle, SYSTEM 3Pro isokinetic exercise equipment was used, and comparisons of MVIC forces of the vastus medialis at different angles were made using surface electromyography (sEMG) measurements. [Results] MVIC forces of the rectus femoris, the vastus medialis, and the vastus lateralis were greatest at 15°, followed by 30° and 45°; MVIC force of the vastus medialis significantly increased at 15°. [Conclusion] We consider isometric exercise with the knee joint angle at 15° is conducive to strengthening the vastus medialis of knee joint osteoarthritis patients during their early exercise periods.
Key words: Isometric, Knee joint osteoarthritis, Vastus medialis

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INTRODUCTION

Degenerative osteoarthritis is one of the most common joint diseases. Although an association between the pathological conditions of osteoarthritis and its symptoms is not clear, it has been often reported as an etiology of pain in the *musculoskeletal system*[1)]. Weakening of the lower limb muscles—in particular, the quadriceps femoris, due to knee joint osteoarthritis—is known to trigger knee pain in many patients[2)]. A weakened quadriceps femoris is related to muscle atrophy and muscular dysfunction, which occurs due to pain resulting from knee joint osteoarthritis[3)]. It is known that mere exercise treatment for knee joint osteoarthritis, before it becomes serious, preserves favorable joint conditions and alleviates pain. Roddy et al. observed that aerobic walking and other exercises that strengthen the quadriceps femoris reduced pain and dysfunction in knee joint osteoarthritis patients[4)]. Mikesky et al. asserted that exercise that reinforces lower limb muscle strength resulted in a lower mean joint space narrowing rate than range of motion exercises in knee joint osteoarthritis patients[5)].

Normal knee joint alignment is enabled by balance between the vastus medialis and the vastus lateralis, and an imbalance of force between the muscles causes patellofemoral pain syndrome, triggering knee joint osteoarthritis[6)]. Nosratollah and Lars reported that moderate isometric exercise that reinforces the vastus medialis was useful for the medial stability of the patella in an early rehabilitation program for knee joint injury[7)]. Many studies have been conducted on vastus medialis muscle activity ratios using electromyography, and on measures for the selective strengthening of the vastus medialis in both unaffected people and patellofemoral pain syndrome patients[8, 9)]. However, research into the activities of the vastus medialis and vastus lateralis, as well as the action potential size of the vastus medialis in knee joint osteoarthritis patients, has been lacking. Therefore, this study measured maximum voluntary isometric contraction (MVIC) force of the vastus medialis at different angles during isometric extension training for the quadriceps femoris, to evaluate the angle at which the MVIC force of the vastus medialis is greatest during isometric knee joint extension, in order to establish an efficient angle for a vastus medialis strengthening exercise.

SUBJECTS AND METHODS

This study recruited 17 subjects(all female) diagnosed as having right knee joint osteoarthritis by an orthopedist at K hospital, Daegu, Korea. The subjects average age, height, and weight were 51.4 ± 1.1 years old, 155.8 ± 1.7 cm, and 55.7 ± 1.4 kg, respectively. Their Kellegren and Lawrence levels were three or lower, and they could walk without an aid. Those who had an operation for knee joint osteoarthritis, who were currently under medication, or who had

Table 1. MVIC measurement values of the different angles

	MVIC Measurement Values at Different Angles (Mean ± SD)		
	15°	30°	45°
Rectus femoris	1016.6 ± 280.4	900.5 ± 177.1	889.6 ± 162.6
Vastus medialis*	995.5 ± 267.5	834.2 ± 216.30	816.4 ± 186.8
Vastus lateralis	1198.6 ± 456.6	1085.1 ± 418.50	984.9 ± 256.9

*$p<0.05$

neurological damage that affected walking or rheumatism were excluded. The purpose of this study, along with the entire procedure of the experiment, was explained to all of the subjects, and their voluntary content was obtained. For high-quality electromyography data, the skin surface was washed with alcohol, and hair on the epidermis was removed using a razor. Surface electrodes were attached to the right lower limb. After the surface electrodes had been attached, subjects sat on the isokinetic exercise equipment (SYSTEM 3Pro, Biodex, USA), and the surface electromyography measurement system was connected. The subject was instructed to conduct isometric extension motions of the lower limbs. Surface electrodes (Ag/Agcl, 3M, Korea) were attached as follows: 2.5 cm medial to one-half of the distance between the anterior superior iliac spine and the superior pole of the patella on the rectus femoris; three-fourths of the distance from the anterior superior iliac spine to the front of the inner collateral ligament of the knee joint; and two-thirds of the distance from below the intertrochanteric line to the superior pole of the patella on the vastus lateralis. The distance between the electrodes was maintained at 3.5 cm, and the ground electrode was attached to the anterior superior iliac spine. The sampling frequency was set at 1024 Hz.

The subjects were seated on the isokinetic exercise equipment with their trunks leaning backward at 10° while maintaining the hip joint at an angle of 90°. In order to prevent the upper body and the lower limbs from shaking, the subject had the upper body fixed on the upper-body exercise table; the patient held the side handles with both hands. The rotation axis of the dynamometer was located in line with the subject's knee joint axis, which facilitated active participation in exercise. For isometric exercise, the lever arm was tied to the power point 1 cm above the lateral malleolus, and the knee joint maximum extension angle was set at 0 °. Electromyographic muscle action potential was measured while the subject maintained isometric contraction for 10 seconds at maximum exertion, at the flexion angles of 15°, 30°, and 45°. Prior to the measurement, the subject practiced each level of exercise three times, and measurement was made five times; a rest of 10 minutes was given to the subject between each level of exercise.

Electromyography signals were analyzed via the Telescan program (Laxtha, Korea). Wave rectification was followed by band-pass filtering of the raw data between 10 Hz and 350 Hz. Full wave rectification was conducted, and MVIC was calculated as the 98% moving average of the measurement result.

One-way analysis of variance (ANOVA) was conducted in order to examine whether there were significant differences in lower limb activity during maximal isometric extension at the different angles, and LSD was conducted for a post-hoc test. SPSS 12.0 for Windows was used for statistical analysis. A p value of less than 0.05 was considered statistically significant.

RESULTS

MVIC of the rectus femoris and the vastus lateralis were greatest at 15°, followed by 30° and 45°, with no significant differences among the angle ($p>0.05$). Likewise, MVIC of the vastus medialis was greatest at 15°, followed by 30° and 45°, with significant differences between 15° and 30°, and 15° and 45° ($p<0.05$) (Table 1).

DISCUSSION

Abnormal activation of the knee joint muscles obstructs normal force distribution and may accelerate disease progression. Knee joint abnormality leads to lower action potential of the vastus medialis, compared to normal people, resulting in pain[10]. Therefore, the main focus of therapy for knee joint osteoarthritis should be directed to the improvement of knee joint muscle balance, in addition to exercise, in order to reinforce the quadriceps femoris[11]. Research has reported different effects of exercise at different knee joint angles. Signorile et al.[12] conducted an isometric extension exercise, combined with internal rotation of the ankle, at flexion angles of 90°, 30° and 5°. They showed that muscular activation increased in the order of the vastus medialis, the vastus lateralis and the rectus femoris as the flexion angle decreased. Similar to the results of this study, a narrower flexion angle led to greater muscular activation of the quadriceps femoris. However, the angle at which the vastus medialis was activated the most was different in the two studies, presumably because Signorile's study involved internal rotation of an ankle.

Boucher et al.[13] reported that muscle activity ratios did not significantly differ between knee flexion angles of 15°, 30°, and 90° in a maximum isometric extension test; however, in the case of patellofemoral pain syndrome patients, activity of the vastus medialis was much lower than that of the vastus lateralis at 15°. In the present study, activity of the vastus medialis at 15° was significantly increased compared to the other angles. We consider the reason for the contrasting study results is the differences in patella alignment used in the two

studies. Han argued[14] that isometric extension exercise of the knee joint at an angle of 10° was most effective at selectively strengthening the vastus medialis, rather than the vastus lateralis. Likewise, this study showed the greatest activation of the vastus medialis of osteoarthritis patients at a similar angle. Stephen et al.[15]. reported that in short arc knee extension, the vastus medialis and the vastus lateralis became more activated at the last 15° than other angles. This agrees with the results of this study, in particular, for the vastus medialis. This is presumably because the vastus medialis becomes particularly active in keeping stability of the knee joint at the far range of extension. This study demonstrated that the most efficient knee joint flexion angle was 15° when knee joint osteoarthritis patients performed isometric knee joint extension exercise to strengthen the vastus medialis. We anticipate that our results will be clinically used in exercise programs for reinforcement of the vastus medialis in knee joint osteoarthritis patients.

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