

Original Article

# Leg Muscle Activation and Distance Setting of the Leg Cycle Ergometer for Use by the Elderly

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**Abstract.** [Purpose] This study verified the leg muscle activities of elderly subjects performing leg cycle ergometer exercise. [Subjects] Forty-one elderly persons were the subjects of this study. [Methods] For the three distances corresponding to knee flexion angles of 15, 45, and 70, the muscle activities of the rectus femoris, biceps femoris, tibialis anterior and lateral gastrocnemius were measured while the subjects exercised on a cycle ergometer. [Results] The rectus femoris and biceps femoris showed statistically significant increases as the distance between the cycle ergometer and the body increased, and the lateral gastrocnemius muscle activation showed a statistically significant increase as the distance from the body to the cycle ergometer decreased. [Conclusion] When the elderly have limb muscle weakness, leg cycle ergometer distances should be adjusted.

**Key words:** Cycle ergometer, Electromyography, Selective muscle strengthening

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## INTRODUCTION

Age-related weakening of muscle strength leads to deterioration in physical functions, and such weakening appears more severely in the lower limbs<sup>1, 2)</sup>. Age-related weakening of muscle strength is the main cause of decreased quality of life of the elderly; therefore, the prevention of muscle strength decrease is a very important task.

Using exercises to improve muscle strength to enhance the quality of life of the elderly is relatively more difficult than for younger adults. This is because difficult and complicated exercises are not suitable for the elderly who have reduced cognitive functions, and since irregular exercise increases instability, there are concerns about falls. As such, safe exercises that have constant movements without an excessive load on the joints should be performed. Cycle ergometer exercise has constant movement, reduces excessive load on the joints, and is done in a sitting position, thereby offering a highly stable exercise<sup>3)</sup>.

In a number of studies of leg cycle ergometer exercises, cycle ergometer exercise has been reported to increase endurance, heart function, balance and gait function<sup>4, 5)</sup>, as well as muscle and physical strength<sup>6)</sup>. These results have been reported to vary with the load and exercise time on a

cycle ergometer.

However, recent studies about muscle usage depend on a maximum distance with a pedal that is directly related to lower limb movement during cycle ergometer use, and it is thought that muscular imbalances may result depending on this distance. Accordingly, this study investigated methods for using a cycle ergometer suitable for the symptoms and conditions of the elderly, by measuring the activities of lower limb muscles at different distances from the ergometer during cycle ergometer exercises.

## SUBJECTS AND METHODS

Forty-one elderly people (21 females and 20 males), without lower limb disorders and who could use a leg cycle ergometer independently, participated in this study (age [mean  $\pm$  SD]: 76.20  $\pm$  6.25 years; height: 161.05  $\pm$  5.64 cm; body mass: 63.40  $\pm$  9.56 kg). The exclusion criteria were: fracture or lesion in lower limb in the previous year, neurological problems, or vestibular or musculoskeletal problems interfering with the capacity to remain standing or sitting. Written informed consent was obtained from all subjects after a full explanation of the experimental purpose and protocol. Moreover, this study complied with the ethical standards of the Declaration of Helsinki.

All physical measurements were taken by an experienced physiotherapist. In order to set the distance between the cycle ergometer and the body of all the participants equally, knee flexion angles were adjusted to 15, 45 and 70° with the ankle joint and hip joint fixed at a 90° angle on the calf support fixture and the pedal. When selecting the distances, the pedal was fixed in the 6 o'clock position. The seat was

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**Table 1.** Muscle activation and distance setting of the leg cycle ergometer (unit:  $\mu\text{V}$ )

	Knee flexion 15°	Knee flexion 45°	Knee flexion 70°
TA	15.56 $\pm$ 9.29	16.03 $\pm$ 7.65	14.30 $\pm$ 5.28
GAS*	11.31 $\pm$ 3.52 <sup>†</sup>	11.77 $\pm$ 4.01 <sup>†</sup>	14.98 $\pm$ 2.99 <sup>‡</sup>
RF*	32.09 $\pm$ 9.76 <sup>†</sup>	23.67 $\pm$ 10.04 <sup>‡</sup>	21.71 $\pm$ 10.52 <sup>‡</sup>
BF*	21.67 $\pm$ 7.43 <sup>†</sup>	15.60 $\pm$ 6.43 <sup>‡</sup>	17.13 $\pm$ 8.57 <sup>‡</sup>

TA, tibialis anterior; GAS, gastrocnemius; RF, rectus femoris; BF, biceps femoris. Each value represents the mean  $\pm$  SD. The values with different superscripts (<sup>†</sup>, <sup>‡</sup>) in the same column are significantly different ( $p < 0.05$ ) by Tukey's measure.

set at a height that enabled a participant to sit with the feet touching the floor, while maintaining the knee joint at 90° and ankle joint at 90°. The fulcrum of the goniometer was centered over the lateral femoral epicondyle. The proximal arm was aligned with the lateral midline of the femur, using the greater trochanter as a reference point. The digital arm was aligned with the lateral midline of the fibula, using the lateral malleolus as a reference point<sup>1)</sup>. At each knee angle, the subjects were asked to maintain a constant rotational speed of 60~70 RPM. The knee angle were selected in a random order. All measurements were performed for one cycle (6 o'clock to 6 o'clock). This study was performed over three days, one condition per day.

In this study, an 8-channel surface electromyography (EMG) system (Myosystem TM DTS, Noraxon Inc., USA) was used to measure muscle activities. For EMG signal processing, the MyoResearch XP master edition 1.07 (Noraxon Inc., USA) program was used. The sampling extraction rate of EMG signals was set to 1,024 Hz and the data were filtered between 20~500 Hz using a bandpass filter and a 60 Hz notch filter. The electrodes (IWC-DTS, 9113A-DTS) were Ag/AgCl electrodes which were attached using hypoallergenic gel. The diameter of the conductivity area was 1 cm and the distance between the electrodes was 2 cm.

Surface EMG was recorded using surface electrodes (IWC-DTS and 9113A-DTS, Noraxon Inc., USA) comprised of three electrodes (positive-ground-negative) to measure the activity of each muscle. Depilation of the attachment sites was performed with a razor and horny parts were removed with sandpaper. The electrodes were attached after cleaning the attachment sites with an alcohol swab to reduce the impedance for accurate collection of electromyograms.

The muscle activities of the rectus femoris, biceps femoris, tibialis anterior, and lateral gastrocnemius were recorded while using the cycle ergometer. In order to increase the reliability of this study, each participant was asked to use the leg cycle ergometer for one minute for each condition, and the average value was used for statistical analyses.

Data were analyzed using the statistical program SPSS version 17, and a  $p$ -value of less than 0.05 was considered significant for all cases. A post-hoc test was performed using Tukey's-test. The data were analyzed using one-way ANOVA to investigate the effect of each condition on muscle activities.

## RESULTS

Statistically significant differences were found for the muscle activities of the rectus femoris and biceps femoris ( $p < 0.05$ ) among the different distances of the body from the cycle ergometer (Table 1). The gastrocnemius showed higher muscle activity as the distance between the leg cycle ergometer and the body increased, and the rectus femoris and biceps femoris showed higher muscle activities as the distance decreased ( $p < 0.05$ ) (Table 1).

## DISCUSSION

The objective of this study was to investigate the effect on elderly subjects of the leg cycle ergometer distance from the body. Our results indicate that the plantar flexor muscle (gastrocnemius) shows higher muscle activation as the distance increased, and the hip flexor and extensor muscle showed higher muscle activation as the distance decreased.

Age-related weakening of the lower limb muscles causes physical deformation, postural instability and instability of movement<sup>7)</sup>. Therefore, proposing an appropriate lower limb muscle strengthening exercise for the elderly is one way of improving the quality of life of the elderly<sup>8)</sup>. Various lower limb muscle strengthening exercises have been presented. However, aging involves not only weakening of lower limb muscle strength, but also the degradation of the sense of balance and cognitive impairment<sup>3)</sup>. As such, exercise performed in a stable position is recommended for lower limb muscle strengthening exercises for the elderly<sup>3)</sup>.

Leg cycle ergometers provide a stable position with a low center of gravity and base of support, and various exercise loads can be applied. It is a standard piece of exercise equipment that uses a whole range of motion.

The results of this study show that as the distance between the leg cycle ergometer and the body increases, the use of the proximal muscle group, i.e. the rectus femoris and biceps femoris, decreases by a statistically significant amount, and that the use of the distal part of the muscle group increases by a statistically significant amount. These results are attributable to the fact that contraction of the rectus femoris and biceps femoris occur at a distance corresponding to a knee flexion angle of 15°, and that ergometer exercise mainly uses the proximal muscles that are significantly affected by the muscle length via the knee joint. In addition, as the distance decreases as in the 70° knee flexion angle, the rectus femoris and biceps femoris muscle length

becomes inappropriately short for contractions during one revolution and to compensate for this, we think that the gastrocnemius muscle, which is affected more by the ROM of the ankle joint than the knee joint, is recruited through the muscle length-tension relationship that has been identified by many previous studies<sup>9)</sup>. The tibialis anterior muscle did not show a statically significant difference, because leg cycle ergometer exercise is an alternating exercise and mainly uses a pushing force. Based on these results, it is possible to ascertain that, as the distance between the leg cycle ergometer and the body decreases, knee joint motion is used more and as the distance increases, ankle joint motion is used more.

To the best of our knowledge, the more the distance is decreased, the more the plantar flexor muscle is selectively activated. The more the distance is increased, the more the hip flexor and extensor muscle are selectively activated during leg cycle ergometer use by the elderly. When elderly people have lower limb muscle weakness, the leg cycle ergometer would need to be adjusted for use. Further studies are needed to analyze the physiological effects of leg cycle ergometer exercise and distance in accordance with long-term use and to analyze discriminative muscle activity according to the angle during one revolution.

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