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# Mean individual muscle activities and ratios of total muscle activities in a selective muscle strengthening experiment: the effects of lower limb muscle activity based on mediolateral slope angles during a one-leg stance

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**Abstract.** [Purpose] The purpose of this study was to provide basic data for research on selective muscle strengthening by identifying mean muscle activities and calculating muscle ratios for use in developing strengthening methods. [Subjects and Methods] Twenty-one healthy volunteers were included in this study. Muscle activity was measured during a one-leg stance under 6 conditions of slope angle: 0°, 5°, 10°, 15°, 20°, and 25°. The data used in the analysis were root mean square and % total muscle activity values. [Results] There were significant differences in the root mean square of the gluteus medius, the hamstring, and the medial gastrocnemius muscles. There were significant differences in % total muscle activity of the medial gastrocnemius. [Conclusion] Future studies aimed at developing selective muscle strengthening methods are likely to yield more effective results by using muscle activity ratios based on electromyography data.

**Key words:** Electromyography, Muscle activity ratio, Selective muscle strengthening

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## INTRODUCTION

Muscle imbalances occur in various forms and cause a variety of diseases[1)]. A number of studies have attempted to identify various methods of selective muscle strengthening using electromyography (EMG) data to prevent and treat muscle imbalances[2–4)]. However, while most of these studies have suggested selective muscle strengthening methods targeting the activity of specific muscles, the actual results have shown simultaneous increases in the activity of the targeted and surrounding muscles[5, 6)].

The purpose of this study was to provide basic data for research on selective muscle strengthening by identifying the means of muscle activities and calculating muscle activity ratios, for use in developing selective muscle strengthening methods.

## SUBJECTS AND METHODS

Twenty-one healthy volunteers (12 males, 9 females; age 26.6 ± 3.0 years, range 22–28 years; weight 64.5 12 ± 9.41 kg, range 45–87 kg; height 168.8 ± 9.19 cm, range 158–187 cm) took part in the experiments. All subjects provided written informed consent, and the study was approved by our institutional review board.

Muscle activity was measured during a one-leg stance, under the following 6 conditions of slope angle: 0°, 5°, 10°, 15°, 20°, and 25°. The slope condition was a mediolateral angle to create the form of an ankle inversion. Each condition was ap-

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plied randomly. To ensure the objectivity of the data, the measurements were taken 3 times under each condition, and average values were employed in the statistical analysis. The muscle activity was maintained for 10 seconds. The muscle activity data for the middle 6 seconds was recorded and averaged for the analysis. To prevent fatigue, the participants took 3-minute breaks. The muscle activity was measured from the standing left leg during the one-leg stance.

Surface EMG (Myosystem TM DTS, Noraxon Inc., USA) was used and a surface electrode (IWC-DTS and 9113A-DTS, Noraxon Inc., USA), consisting of 3 electrodes (positive-ground-negative), was used to measure the activity of the gluteus medius, the hamstring, the biceps femoris, the medial gastrocnemius, and the lateral gastrocnemius on the left side. The surface electrodes were attached according to the SENIAM (Surface Electromyography for the Non-Invasive Assessment of Muscles) system. The frequency of the EMG signal was set at 20–500 Hz and the sampling frequency was 1,024 Hz, with notch filter 60 Hz. This study used data for the root mean square (RMS) and % total muscle activity (%TA). The formula for the % individual muscle activity is as follows.

$$\frac{\text{Specific muscle activity} \times 100}{\text{Total muscle activity measured in the experiment}}$$

SPSS statistical package software (version 18.0; SPSS, Chicago, IL, USA) was used to analyze the differences in the activities of each muscle. The repeated-measures one-way analysis of variance with a factor task was used to compare muscle contraction at different angles of slope. The level of significance was set at $p \leq 0.05$.

## RESULTS

Table 1 shows muscle activity for each condition. There were significant differences in the gluteus medius, the hamstring, and the medial gastrocnemius muscles ($p<0.05$). Table 2 shows the muscle activity ratio for each condition. There were significant differences in the medial gastrocnemius ($p<0.05$).

## DISCUSSION

The results of this study showed that for the RMS values, the activity of the gluteus medius, the hamstring, and the medial gastrocnemius muscles changed according to the mediolateral slope angle. An increase in the angle resulted in a gradual increase in the activity of the above 4 muscles. This result suggests that increases in the slope angle when performing a one-leg stance are helpful for muscle strengthening, and that targeting of a single muscle enables selective strengthening of that muscle. However, this result may also be interpreted as an increase in the overall activity of all muscles due to increases in the level of difficulty.

The results for muscle usage ratios exhibited a marked increase for the medial gastrocnemius compared to the other muscles. The results shown in Tables 1 and 2 suggest that while the activity of all muscles increased, the activity of the medial

**Table 1.** Muscle activation according to the mediolateral slope of various angles (Unit: μV)

| | 0° ramp | 5° ramp | 10° ramp | 15° ramp | 20° ramp | 25° ramp |
|---|---|---|---|---|---|---|
| GM* | 35.2 ± 2.1 | 32.7 ± 2.3 | 34.5 ± 4.0 | 43.3 ± 2.9 | 39.1 ± 2.2 | 50.4 ± 4.7 |
| Hams* | 15.8 ± 1.7 | 21.1 ± 3.1 | 23.1 ± 3.9 | 24.7 ± 2.2 | 15.2 ± 1.4 | 27.0 ± 2.2 |
| biFEM | 8.8 ± 1.0 | 7.9 ± 0.9 | 9.7 ± 1.4 | 10.7 ± 1.6 | 10.2 ± 2.0 | 12.6 ± 1.2 |
| Med GAS* | 37.8 ± 7.7 | 44.5 ± 5.7 | 50.0 ± 4.6 | 58.7 ± 4.0 | 55.2 ± 3.8 | 59.6 ± 4.3 |
| Lat GAS | 20.4 ± 3.7 | 17.6 ± 3.0 | 17.8 ± 2.6 | 18.5 ± 2.7 | 17.1 ± 1.5 | 24.6 ± 3.3 |

*p<0.05, mean ± SE.
GM: gluteus medius; hams: hamstring; biFEM: Biceps Femoris; Med GAS: medial gastrocnemius; Lat GAS: lateral gastrocnemius

**Table 2.** Muscle activation ratios according to the mediolateral slope of various angles (Unit: % total activity)

| | 0° ramp | 5° ramp | 10° ramp | 15° ramp | 20° ramp | 25° ramp |
|---|---|---|---|---|---|---|
| GM | 34.1 ± 2.3 | 31.0 ± 3.0 | 28.4 ± 3.1 | 28.0 ± 1.1 | 28.4 ± 1.0 | 28.9 ± 1.3 |
| Hams | 14.4 ± 1.7 | 15.5 ± 1.8 | 15.0 ± 1.5 | 15.6 ± 0.7 | 12.0 ± 1.3 | 15.5 ± 0.3 |
| biFEM | 8.7 ± 1.2 | 6.1 ± 0.3 | 6.5 ± 0.8 | 6.8 ± 1.2 | 7.1 ± 1.4 | 7.3 ± 0.5 |
| Med GAS* | 26.9 ± 2.6 | 33.7 ± 1.3 | 36.6 ± 1.1 | 37.9 ± 0.6 | 39.3 ± 1.2 | 34.7 ± 0.3 |
| Lat GAS | 15.7 ± 1.6 | 13.5 ± 1.5 | 13.2 ± 1.4 | 11.4 ± 1.1 | 12.9 ± 1.2 | 13.4 ± 1.3 |

*p<0.05, mean ± SE

gastrocnemius increased at a more significant rate; therefore, increases in the slope angle are more effective in selective strengthening of the medial gastrocnemius. Thus, future studies aimed at developing selective muscle strengthening methods are likely to yield more effective results by using muscle activity ratios based on EMG data.

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