Isometric Contraction of an Upper Extremity and Its Effects on the Contralateral Lower Extremity

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Abstract. [Purpose] The aim of this study was to examine effects of the isometric contraction of an upper limb in a supine position on the muscle activity of a healthy adult in the contralateral lower limb. [Subjects] The subjects were 40 healthy adults (35 males and 5 females). [Methods] The muscle activity of the rectus femoris (RF), biceps femoris, anterior tibialis, and medial gastrocnemius (MG) of the contralateral lower limb was measured using electromyography while the subjects flexed, extended, abducted, and adducted the shoulder joint of an upper limb. [Results] The muscle activity of the RF of the contralateral lower limb was significantly high when the subject flexed the shoulder joint of an upper limb, and the muscle activity of the MG of the contralateral lower limb was significantly high when the subject adducted the shoulder joint of an upper limb. [Conclusion] The isometric contraction that results from flexion and adduction of the shoulder joint of an upper limb in a supine position is considered to selectively affect the RF and MG activity of the contralateral lower limb.

Key words: Muscle activity, Isometric contraction, Contralateral lower extremity

INTRODUCTION

In general, different direct therapeutic approaches have been used as exercise treatment methods for the neurological forms of some conditions to improve the functions of the affected side; however, indirect therapeutic approaches aimed at helping the affected side recover using the body parts on the unaffected side have also been said to be effective¹. With regard to indirect treatment, Hellebrandt et al. reported that maximal exercise of the unilateral limbs triggered muscle tone in the contralateral body part without exercise and that the flexion pattern of the upper limb accompanying contraction of the abdominal muscles indirectly activated the trunk muscles. In addition, Devine et al. observed that contralateral exercise was conducive to reducing muscular atrophy, maintaining motor coordination, and enhancing the muscle strength of damaged lower extremities, and therapists were able to improve the treatment and rehabilitation of patients with neuromuscular system diseases and musculoskeletal problems. In the clinical field, the application of indirect treatment is explained by the concept of cross education, and it is now being supported by research, as research results indicated that training on the unaffected side influences the functions of the affected side. al.⁶ verified that resistance training on one side triggered changes in muscle strength on the opposite side, and Bemben and Murphy reported that short-term unilateral side resistance training resulted in increased muscle strength in the untrained extremities. Therefore, indirect treatment using cross education has been proposed as a method to help patients with hemiparesis, patients who have undergone hip or knee joint replacement, and patients with plaster fixation of the unilateral limbs for muscular and functional recovery of the paretic side⁸. Prior studies have noted that muscle training with the paretic side lower limb increased the muscle strength of the contralateral lower limb⁴ ⁵, ⁶, ⁸, but other studies did not obtain such effects⁹ ⁻¹². As in previous studies, it is difficult to examine precise and detailed changes in the muscle activity of the lower extremities using EMG, and Korean studies that look at the muscle activity of the contralateral lower limb through isometric contraction of an upper limb are lacking, and there are conflicting opinions about the effects of indirect treatment. Accordingly, this study was conducted to examine changes the lower-limb muscle activity of healthy subjects based on the movement of the upper limbs. Its aim was to examine the muscle activity of the contralateral lower limb according to isometric contraction of an upper limb in a supine position and to suggest an efficient means of upper limb movement with the aim of increasing the contraction of the contralateral lower limb muscles, thereby presenting basic data for rehabilitation treatment of early hemiplegic patients who have difficulty with physical postural control.

SUBJECTS AND METHODS

The subjects of this study were 40 healthy adults (35
muscle activity, and surface electrodes were attached to the
Barbara, CA, USA) was employed to measure changes in
maintain 50% of the maximal contractility 13).

The subjects lay in a supine position, spread their legs
shoulder-width apart, placed their toes in a neutral position,
and maintained an anatomical position for initiation of the
exercise. Muscle activity was recorded while the subjects
conducted isometric contraction, flexing the shoulder joint
at 20 cm from the ground for flexion, extension, abduction,
and adduction of the shoulder joint. All the subjects con-
ducted isometric flexion, extension, abduction, and adduc-
tion of the shoulder joint using the dominant side upper ex-
trremity, to ensure consistency in the experimental method,
and the muscle activity of the rectus femoris (RF), biceps
temoris (BF), anterior tibialis (AT), and medial gastrocne-
mus (MG) was recorded. The four kinds of shoulder joint
exercise conditions were randomly applied to the subjects.

To provide the same adequate resistance for all subjects,
a handheld dynamometer was used. Resistance was applied
to the proximal part of the front, back, medial, and lateral
parts of the arm while the subjects conducted isometric flexion,
extension, abduction, and adduction of the shoulder joint.
Visual feedback was provided to the patients and the evalua-
tor with the handheld dynamometer, so constant resistance
against the subjects could be continuously main-
tained for five seconds. During the measurements, the ex-
tension of the elbow joint was maintained, and when other
compensation appeared, another measurement was taken.
The subjects rested for one minute between exercises. They
performed isometric contraction for five seconds and re-
peated it three times. The average value of the three mea-
surements was used for the final analysis. The maximal iso-
metric contraction of each upper extremity movement was
obtained using the handheld dynamometer (Commander™,
JTECH Medical, Salt Lake City, UT, USA) to provide the
same appropriate resistance, and resistance was provided to
maintain 50% of the maximal contractility15).

Surface EMG (MP150, BIOPAC Systems Inc., Santa
Barbara, CA, USA) was employed to measure changes in
muscle activity, and surface electrodes were attached to the
RF, BF, AT, and MG. EMG signals were sent to the MP150
system and converted into digital signals. Data were pro-
cessed using the Acqknowledge software (version 4.01) on
a personal computer. The average value of each subject’s
EMG signals was expressed as a percentage of the maximal
voluntary isometric contraction.

In this study, repeated one-way analysis of variance was
conducted in order to examine the muscle activity of the
contralateral lower limb following isometric contraction of
the upper limb, and the Bonferroni method was used as a
post hoc test. The data for this study were statistically pro-
cessed using SPSS 12.0 for Windows. The significance level
was set at α = 0.05.

RESULTS

According to the study results, the muscle activity of the
RF of the contralateral lower limb was significantly high
when the shoulder joint of an side upper limb was flexed
(p<0.05), and the muscle activity of the MG of the contra-
lateral lower limb was significantly high when the shoulder
joint of an limb was adducted (p<0.05) (Table 1).

DISCUSSION

In order to examine the effects of isometric contraction
of an upper extremity on the muscle activity of contralateral
the opposite side lower extremity in a healthy adult, this
study measured the muscle activity of the RF, BF, AT, and
MG of the contralateral site lower extremity in response to
flexion, extension, abduction, and adduction of the shoulder
joint of the an upper extremity.

Tarnanen et al.14) examined the trunk muscle activity of
the same and opposite sides in response to isometric con-
traction of one upper extremities, and they reported that
the activity of the multifidus muscle of both the same and
opposite sides increased during the horizontal abduction of
the shoulder joint. In a study of the activity of the spinal
erector muscle when subjects supported a weight loaded on
the upper extremities in a standing position, Crommert et
al.15) noted that the activity of the muscle increased more
when the subjects supported the loaded weight by horizon-
tally extending the arms at the height of the knee joint than
when they supported the loaded weight without hori-
izontally extending the arms, and they asserted that the loca-
tion of the resistance loaded on the extremities significantly
affected the activity of the spinal extensor muscle. Park et
al.16) asserted that isometric contraction of the hip joint on

<table>
<thead>
<tr>
<th></th>
<th>Flexion**</th>
<th>Extension</th>
<th>Adduction*</th>
<th>Abduction</th>
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<tbody>
<tr>
<td>RF</td>
<td>8.1±7.7</td>
<td>1.8±2.7</td>
<td>4.7±7.5</td>
<td>3.8±5.1</td>
</tr>
<tr>
<td>BF</td>
<td>1.1±0.9</td>
<td>3.7±5.5</td>
<td>1.7±2.8</td>
<td>2.0±2.9</td>
</tr>
<tr>
<td>AT</td>
<td>3.1±7.5</td>
<td>2.4±4.7</td>
<td>2.6±6.7</td>
<td>2.3±4.5</td>
</tr>
<tr>
<td>MG</td>
<td>3.5±3.2</td>
<td>2.9±2.8</td>
<td>5.3±4.9</td>
<td>2.6±1.7</td>
</tr>
</tbody>
</table>

*: M±SD, RF: rectus femoris, BF: biceps femoris, AT: anterior tibialis, MG: medial
gastrocnemius, *,p<0.05, **: p<0.01, *: repeated one-way ANOVA
one side may increase the trunk muscle activity on the opposite side and that the isometric contraction in flexion and abduction of the hip joint on one side influenced the relative activity of the muscles, such as the multifidus muscle engaging in trunk postural control. In a study of patients with a fixed lower extremity resulting from damage it had suffered, Arai et al.\(^{17}\) reported that exercise of the contralateral lower extremity comprised of proprioceptive neuromuscular facilitation exercises increased the contractility of the affected side quadriceps femoris muscle more than ordinary exercise consisting of diverse resistance exercises. Sato and Maruyama\(^{18}\) advised that, among the techniques of proprioceptive neuromuscular facilitation (PNF) when isometric resistance exercises were performed by an upper extremity in the final position of the flexion-abduction-external rotation pattern of PNF, the extension force of the lower extremity on the opposite side increased. Yoo et al.\(^{19}\) reported that during unilateral lower-limb PNF pattern training, abdominal hollowing significantly increased the muscle activity of the vastus lateralis, the tibialis anterior, the semitendinosus, and the gastrocnemius of contralateral lower extremity.

According to the results of the present study, when the subjects flexed the shoulder joint of an upper extremity, the muscle activity of the RF of the contralateral lower extremity was significantly high, and when the subjects adducted the shoulder joint of an upper extremity, the muscle activity of the MG of the contralateral lower extremity was significantly high. Regarding this result, Myers et al.\(^{20}\) explained that the human body responded as a whole when one part of the body moved, and the only tissue that could perform functional intervention was the connective tissue; they approached the interactions and the overall functions of different physical systems through the concept of lines, and they expressed interactions using front, back, lateral, arm, spinal, and oblique lines. As for the functional connectivity between the upper extremity and contralateral opposite side lower extremity applied in the present study, flexion and adduction of the shoulder joint of an upper extremity led to high muscle activity in the RF and the MG due to anatomical connectivity between the arm line of the upper extremity and the spinal line, according to the lines proposed by Myers et al.\(^{20}\).

The present study has some limitations. First, it is difficult to discuss long-term treatment effects with the present study results because isometric contraction of the upper extremity was conducted for a relatively short period of time. Therefore, long-term research is necessary. Second, the possibility of latent signals occurring during surface EMG due to other nearby soft tissues cannot be excluded because of the characteristics of the measurement method. Third, the muscle activity was measured with subjects in a supine position only, and the muscle activity according to different postures and locations was not considered. Thus, future research should examine how isometric contraction of an upper extremity according to different postures and locations influences the muscle activity of healthy adults in the lower extremity on the opposite side.

**REFERENCES**