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Original Article

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

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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 effective[1)]. With regard to indirect treatment, Hellebrandt et al.[2)] 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.[3)] 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[4, 5)]. Using electromyography (EMG), Shima et al.[6)] verified that resistance training on one side triggered changes in muscle strength on the opposite side, and Bemben and Murphy[7)] 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 side[8)]. Prior studies have noted that muscle training with the paretic side lower limb increased the muscle strength of the contralateral lower limb[4–8)], but other studies did not obtain such effects[9–12)].

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

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Table 1. Comparison of the opposite side lower extremity muscles according to isometric contraction of the unilateral side upper extremity (Unit: %)

	Flexion**	Extension	Adduction*	Abduction
RF	8.1±7.7[a]	1.8±2.7	4.7±7.5	3.8±5.1
BF	1.1±0.9	3.7±5.5	1.7±2.8	2.0±2.9
AT	3.1±7.5	2.4±4.7	2.6±6.7	2.3±4.5
MG	3.5±3.2	2.9±2.8	5.3±4.9	2.6±1.7

[a]: M±SD, RF: rectus femoris, BF: biceps femoris, AT: anterior tibialis, MG: medial gastrocnemius, *:$p<0.05$, **: $p<0.01$, *: repeated one-way ANOVA

males, 5 females) in their 20s who were undergraduates at Y University, Chungcheongbuk-do, Republic of Korea. Their average age, weight, and height were 21.6 years old, 68.6 kg, and 174.4 cm, respectively. Prior to the experiment, the subjects were informed about the purpose of this study and exercise method, and they voluntarily consented to participate in this experiment and signed an agreement according to the ethical Standards of the Declaration of Helsinki. Those who had received muscle strengthen training in the previous six months or who had orthopedic or neurological damage were excluded.

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 conducted isometric flexion, extension, abduction, and adduction of the shoulder joint using the dominant side upper extremity, to ensure consistency in the experimental method, and the muscle activity of the rectus femoris (RF), biceps femoris (BF), anterior tibialis (AT), and medial gastrocnemius (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 evaluator with the handheld dynamometer, so constant resistance against the subjects could be continuously maintained for five seconds. During the measurements, the extension 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 conducted contraction for five seconds and repeated it three times. The average value of the three measurements was used for the final analysis. The maximal isometric 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 contractility[13].

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 processed 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 processed using SPSS 12.0 for Windows. The significance level was set at $\alpha = 0.05$.

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 contralateral 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 contraction 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 horizontally extending the arms at the height of the knee joint than when they supported the loaded weight without horizontally extending the arms, and they asserted that the location 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 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 ont 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

1) Kim JM, Lee CH: Neurological physical therapy. Jungdam, Seoul, 2001, 197–201.
2) Hellebrandt FA, Parrish AM, Houtz SJ: The influence of unilateral exercise on the contralateral limb. Arch Phys Med Rehabil, 1947, 28: 76–85. [Medline]
3) Devine KL, LeVeau BF, Yack HJ: Electromyographic activity recorded from an unexercised muscle during maximal isometric exercise of the contralateral agonists and antagonists. Phys Ther, 1981, 61: 898–903. [Medline]
4) Hortobágyi T, Scott K, Lambert J, et al.: Cross-education of muscle strength is greater with stimulated than voluntary contractions. Mot Contr, 1999, 3: 205–219. [Medline]
5) Stromberg BV: Contralateral therapy in upper extremity rehabilitation. Am J Phys Med, 1986, 65: 135–143. [Medline]
6) Shima N, Ishida K, Katayama K, et al.: Cross education of muscular strength during unilateral resistance training and detraining. Eur J Appl Physiol, 2002, 86: 287–294. [Medline] [CrossRef]
7) Bemben MG, Murphy RE: Age related neural adaptation following short term resistance training in women. J Sports Med Phys Fitness, 2001, 41: 291–299. [Medline]
8) Kim KH: effect of proprioceptive neuromuscular facilitation applied to the unilateral upper extremity on the muscle activation of contralateral lower extremity. Eulji University, Dissertation of master's degree, 2005.
9) Gardner GW: Specificity of strength changes of the exercised and nonexercised limb following isometric training. Res Q, 1963, 34: 98–101.
10) Garfinkel S, Cafarelli E: Relative changes in maximal force, EMG, and muscle cross-sectional area after isometric training. Med Sci Sports Exerc, 1992, 24: 1220–1227. [Medline] [CrossRef]
11) Housh DJ, Housh TJ, Johnson GO, et al.: Hypertrophic response to unilateral concentric isokinetic resistance training. J Appl Physiol 1985, 1992, 73: 65–70. [Medline]
12) Meyers CR: Effects of two isometric routines on strength, size, and endurance in exercised and nonexercised arms. Res Q, 1967, 38: 430–440. [Medline]
13) Chon SC, Chang KY, You JS: Effect of the abdominal draw-in manoeuvre in combination with ankle dorsiflexion in strengthening the transverse abdominal muscle in healthy young adults: a preliminary, randomised, controlled study. Physiotherapy, 2010, 96: 130–136. [Medline] [CrossRef]
14) Tarnanen SP, Ylinen JJ, Siekkinen KM, et al.: Effect of isometric upper-extremity exercises on the activation of core stabilizing muscles. Arch Phys Med Rehabil, 2008, 89: 513–521. [Medline] [CrossRef]
15) Crommert ME, Ekblom MM, Thorstensson A: Activation of transversus abdominis varies with postural demand in standing. Gait Posture, 2011, 33: 473–477. [Medline] [CrossRef]
16) Park HJ, Sim SM, Choi JD, et al.: The effects of isometric lower limb contraction on the activation of contralateral trunk muscles in healthy young adults in supine position. Phys Ther Kor. 2012, 19: 11–19. [CrossRef]
17) Arai M, Shimizu H, Shimizu ME, et al.: Effects of the use of cross-education to the affected side through various resistive exercises of the sound side and settings of the length of the affected muscles. Hiroshima J Med Sci, 2001, 50: 65–73. [Medline]
18) Sato H, Maruyama H: The effects of indirect treatment of proprioceptive neuromuscular facilitation. J Phys Ther Sci, 2009, 21: 189–193. [CrossRef]
19) Yoo B, Park H, Heo K, et al.: The Effects of Abdominal Hollowing in Lower-limb PNF Pattern Training on the Activation of Contralateral Muscles. J Phys Ther Sci, 2013, 25: 1335–1338. [Medline] [CrossRef]
20) Myers TW, Juhan D, Chaitow L: Anatomy train: Myofascial meridians for manual and movement therapists, 1st ed. UK: Churchilll Livingstone, Elservier Science Limited, 2001.