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Original Article

Comparison of Lower Limb Muscle Activity during Eccentric and Concentric Exercises in Runners with Achilles Tendinopathy

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Abstract. [Purpose] This study aimed to identify changes in muscle activation by comparing muscle activities of the affected side (AS) and non-affected side (NAS) during eccentric and concentric exercises in runners with unilateral Achilles tendinopathy. [Subjects] The study included 18 participants consisting of men and women with chronic Achilles tendinopathy in a single leg who had more than 1 year of running experience. [Methods] All subjects performed concentric and eccentric exercise with the Achilles tendon moving from full plantar flexion to full dorsiflexion for 8 seconds, and electromyography data was obtained. [Results] All muscles examined showed a significant increase in %maximal voluntary contraction (MVC) with concentric exercise compared with eccentric exercise. Compared with the NAS, the AS showed significant increases in %MVC of the rectus femoris, tibialis anterior, and lateral gastrocnemius. All interaction effects of exercise methods and injuries showed statistically significant changes. [Conclusion] Runners with Achilles tendinopathy show increases in medial gastrocnemius activity when performing eccentric exercise.

Key words: Achilles tendinopathy, Eccentric exercise, Electromyography

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INTRODUCTION

Among runners, Achilles tendonitis is a significant disability that often causes loss of an entire season of competition[1)]. The occurrence of this disease is related to the individual's activity level[2)], and it has been reported to account for 7–9% of sports injuries and 6–18% of running injuries that elite athletes endure[3)]. Achilles tendinopathy occurs in almost every type of sport, and symptoms develop due to overuse that occurs during repetitive training[4)].

In a clinical setting, eccentric exercise is used as a part of a therapeutic exercise program for pain relief; however, the exact pathophysiology of Achilles tendinopathy is unknown. Recent studies have tried to determine the mechanisms underlying the beneficial effects of eccentric exercise. For instance, Sole, Milosavljevic, Nicholson, and Sullivan (2011) concluded that during eccentric exercise, a difference in electromyography (EMG) activity is rarely observed between patients with tendinopathy and normal persons when the length of the tendon is short, but the difference becomes appreciable as the length of the tendon increases[5)]. In another study, Henriksen, Aaboe, Graven-Nielsen, Bliddal, and Langberg (2011) ascertained that Achilles tendon pain reduced EMG activity in agonistic, synergistic, and antagonistic muscles[6)]. However, in that study, pain was induced in normal subjects using intratendinous injections of hypertonic saline. No study has focused on subjects with Achilles tendinopathy. Comparisons of changes in lower limb muscle activity during eccentric and concentric exercises between the non-affected side (NAS) and affected side (AS) are essential to determining the mechanisms responsible for the beneficial effects of eccentric exercise.

This study aims to identify changes in muscle activation by comparing muscle activities of the AS and NAS during eccentric and concentric exercise in runners with unilateral Achilles tendinopathy in order to determine methods for preventing running injury and the pathological characteristics of Achilles tendinopathy.

SUBJECTS AND METHODS

A single-blind, cross-sectional study was performed. The project was approved by the University of Sahmyook Research Ethics Review Committee (SYUIRB2010-007, 27 February 2010), and the study protocol was conducted in strict accordance with the Declaration of Helsinki. Written informed consent was obtained from each subject. This study included 18 participants which consisting of men and women chronic Achilles tendinopathy in a single leg and more than 1 year of running experience. Subjects were recruited from the K Rehabilitation Hospital Research Center located in Seoul, South Korea. The selection criteria for subjects included a diagnosis of Achilles tendinopathy

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based on structural abnormalities found on only one side by ultrasonography, a diagnosis of Achilles tendinopathy for at least 6 months, availability for outpatient follow-up, and unaided movement. Nine of the subjects were male, and nine were female. The mean age, height, and weight were 26.22±4.14 years old, 166.22±9.33 cm, 63.06±12.08 kg, respectively. All subjects had an electrode attached to both the AS and NAS, and then maximal voluntary contraction (MVC) readings were obtained using isometric contraction according to the methods of manual muscle testing. After 1 minute of rest, the subjects performed concentric exercise with the Achilles tendon moving from full plantar flexion to full dorsiflexion for 8 seconds. This exercise was repeated 5 times with bare feet in order to acquire EMG signals, as suggested for a pre-test[7]. After another 1 minute of rest, the researcher collected data by administering eccentric exercise with the Achilles tendon moving from full plantar flexion to full dorsiflexion. While subjects were performing concentric and eccentric exercises, the floor behind the heel was removed so that the calcaneus did not touch the ground. For assessment of EMG data, we used a Trigno™ Wireless system(Delsys, Boston, MA, USA) to determine muscle activation during eccentric and concentric exercise. Markers were attached to the rectus femoris, tibialis anterior, peroneus longus, medial gastrocnemius, and lateral gastrocnemius, as suggested for a pre-test[7]. MVC and peak EMG signal data were collected using MyoResearch XP ME 1.06, since the EMG data measured in the experiment were raw data that were directly obtained from activating muscles. We used a 10–380 Hz band-passfilter to filter out noise in the raw data and then conducted full-wave rectification to process negative figures into positive ones. In this manner, peak EMG signals were collected when each MVC was being performed during eccentric and concentric exercise, and they were later divided by the MVC and multiplied by 100 to determine the %MVC of each muscle. Statistical analysis was conducted using SPSS ver 12.0 (SPSS Inc., Chicago, USA). This study identified general characteristics of runners with Achilles tendinopathy and calculated means and standard deviations using descriptive statistics to compare the maximum muscle activations of the AS and NAS during eccentric and concentric exercises. We also used 2-way repeated ANOVAs (2 × 2) to compare differences between the AS and NAS and during ipsilateral eccentric and concentric exercises. A significance level (α) of 0.05 or less was used for all statistical data.

RESULTS

Table 1 shows the difference between maximum muscle activations of the AS and NAS during eccentric and concentric exercises performed by runners with Achilles tendinopathy. All the muscles examined showed significant increases ($p < 0.05$) in muscle activation with concentric exercise compared with eccentric exercise. Compared with the NAS, the AS showed a more significant increase ($p < 0.05$) in activation of the rectus femoris, tibialis anterior, and lateral gastrocnemius. Interaction effects between exercise methods and injury side all showed statistically significant changes ($p < 0.05$).

Table 1. Difference in %MVC during eccentric and concentric exercise

	Side	Eccentric exercise	Concentric exercise
Rectus femoris (%)	AS	35.7±9.3	61.1±13.8*
	NAS	24.5±9.2#	32.9±14.1*#
Tibialis anterior (%)	AS	12.2±6.2	21.8±12.0*
	NAS	2.8±1.7#	2.8±1.8*#
Peroneus longus (%)	AS	30.3±17.6	48.7±27.4*
	NAS	27.1±13.7	30.9±17.5*
Lateral gastrocnemius (%)	AS	25.4±20.7	37.3±36.1*
	NAS	42.0±11.7#	76.0±21.4*#
Medial gastrocnemius (%)	AS	44.9±34.4	13.5±9.5*
	NAS	20.3±9.5	24.8±18.6*

Values are means±SD. * significant difference between exercise methods (p<0.05). # significant difference between injury sides (p<0.05).

DISCUSSION

Concentric exercise shows greater EMG activation than eccentric exercise for normal muscles because the body rests during the period of cross-bridge formation in eccentric exercise, whereas this is not the case during cross-bridge formation in concentric exercise[8]. In addition, concentric exercise recruits more motor units during performance of the same task and leads to 3 times greater energy expenditure than that during eccentric exercise[9]. Therefore, the present study revealed that concentric exercise induces higher maximum muscle activation in every muscle except the medial gastrocnemius of the AS; specifically, relatively high levels of statistical significance were found for the rectus femoris, tibialis anterior, peroneus longus, and lateral gastrocnemius, and previous studies comparing concentric and eccentric exercises have also reported that peak EMG signals increased significantly in all muscles of the lower limbs[10]. Another study also reported that eccentric exercise of the lower limbs is more effective than concentric exercise in inducing a reduction in EMG signals from the knee extensors[11].

The results of present study revealed that compared with concentric exercise, eccentric exercise induced a higher %MVC in the medial gastrocnemius of the AS. The peak muscle activity of the medial and lateral gastrocnemius changes depending on the mechanical frame of the lower limb. When the lower limb enters the phase of external rotation, the %MVC of the medial gastrocnemius increases as eccentric exercise is performed[12]. As the exercise is performed in the upright position, when the lower limb enters the phase of external rotation, the pronation of the ankle increases to compensate for body balance. Achilles tendinopathy occurs when pronation of the ankle increases exceptionally so that lateral deviation of the subtalar joint occurs[13]. The transformation in lower limb alignment because of this causality reduces the use of the lateral gastrocnemius and increases the %MVC of the medial gastrocnemius. The external rotation of the lower limb during the course of concentric exercise did not show any statistically significant differences between the medial and lateral gastrocnemius, but the %MVC of the medial gastrocnemius showed a significant increase when eccentric exercise was performed[12)]. In addition, previous studies have reported that separate analyses of medial and lateral gastrocnemius EMG findings reveal that when the dorsiflexion range of motion is narrower, the peak EMG signal is greater in the medial gastrocnemius[14)]. This is in accordance with our results, taking into consideration the fact that the ankle range of motion is reduced in patients with Achilles tendinopathy compared with normal people.

The results of this study revealed that during both eccentric and concentric exercises, the NAS has greater %MVCs in the rectus femoris, tibialis anterior, and peroneus longus. However, the %MVC of the gastrocnemius muscle, except the medial gastrocnemius, on the AS was higher than that of the NAS. A previous study compared EMG findings between a patient group consisting of subjects with pain in the Achilles tendon and a control group; this study concluded that the peak Achilles tendon strength was weaker in the patient group[15)]. Another study stated that EMG signals of the gastrocnemius were significantly decreased in patients with Achilles tendinopathy compared with controls[16)].

As we discussed, when runners with Achilles tendinopathy perform eccentric and concentric exercises, differences are observed in lower limb muscle activity; importantly, runners with Achilles tendinopathy experience an increase in medial gastrocnemius activity when performing eccentric exercise. From the clinical viewpoint, extensive effort is required to determine the various muscle changes induced by diseases in order to prevent secondary Achilles tendinopathy.

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