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

INTRODUCTION

Among runners, Achilles tendonitis is a significant disability that often causes loss of an entire season of competition1). The occurrence of this disease is related to the individual’s activity level2), and it has been reported to account for 7–9% of sports injuries and 6–18% of running injuries that elite athletes endure3). Achilles tendinopathy occurs in almost every type of sport, and symptoms develop due to overuse that occurs during repetitive training4).

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 increases5). In another study, Henriksen, Aaboe, Graven-Nielsen, Bliddal, and Langberg (2011) ascertained that Achilles tendon pain reduced EMG activity in agonistic, synergistic, and antagonistic muscles6). 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...
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 exercises performed by runners with Achilles tendinopathy and calculated means and standard deviations using descriptive statistics to compare activations of the AS and NAS during eccentric and concentric exercise, and between injury sides 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 (%) | 35.7±9.3 | 61.1±13.8* |
| Tibialis anterior (%) | 24.5±9.2* | 32.9±14.1* |
| Peroneus longus (%) | 12.2±6.2 | 21.8±12.0* |
| Longus (%) | 2.8±1.7* | 2.8±1.8* |
| Lateral gastrocnemius (%) | 30.3±17.6 | 48.7±27.4* |
| Medial gastrocnemius (%) | 27.1±13.7 | 30.9±17.5* |
| Lateral (%MSI) | 25.4±20.7 | 37.3±36.1* |
| Medial (%MSI) | 42.0±11.7* | 76.0±21.4* |
| Lateral (%MSI) | 44.9±34.4 | 13.5±9.5* |
| Medial (%MSI) | 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. In addition, eccentric exercise recruits more motor units during performance of the same task and leads to 3 times greater energy expenditure than that during eccentric exercise. 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. Another study also reported that eccentric exercise of the lower limbs is more effective than concentric exercise in reducing a reduction in EMG signals from the knee extensors.

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 vastus medialis increases as eccentric exercise is performed. 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. The transformation in lower limb alignment because of this causality reduces the use of the lateral gas-
trocnenius 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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REFERENCES

1) Beneka AG, Malliou PC, Benekas G: Water and land based rehabilitation for Achilles tendinopathy in an elite female runner. Br J Sports Med, 2003, 37: 535–537. [Medline] [CrossRef]
2) Kujala UM, Sarna S, Kaprio J: Cumulative incidence of achilles tendon rupture and tendinopathy in male former elite athletes. Clin J Sport Med, 2005, 15: 133–135. [Medline] [CrossRef]
3) Fahlström M, Lorentzon R, Alfredson H: Painful conditions in the Achilles tendon region in elite badminton players. Am J Sports Med, 2002, 30: 51–54. [Medline]
4) Woods C, Hawkins R, Hulse M, et al.: The Football Association Medical Research Programme: an audit of injuries in professional football-analysis of preseason injuries. Br J Sports Med, 2002, 36: 436–441, discussion 441. [Medline] [CrossRef]
5) Sole G, Milosavljevic S, Nicholson HD, et al.: Selective strength loss and decreased muscle activity in hamstring injury. J Orthop Sports Phys Ther, 2011, 41: 354–363. [Medline] [CrossRef]
6) Henriksen M, Abboe J, Graven-Nielsen T, et al.: Motor responses to experimental Achilles tendon pain. Br J Sports Med, 2011, 45: 393–398. [Medline] [CrossRef]
7) Rees JD, Lichtwark GA, Wolman RL, et al.: The mechanism for efficacy of eccentric loading in Achilles tendon injury; an in vivo study in humans. Rheumatology (Oxford), 2008, 47: 1493–1497. [Medline] [CrossRef]
8) De Ruiter CJ, De Haan A: Similar effects of cooling and fatigue on eccentric and concentric force-velocity relationships in human muscle. J Appl Physiol 1985, 1981, 90: 2109–2116. [Medline]
9) Hedayatpour N, Falla D, Arendt-Nielsen L, et al.: Motor unit conduction velocity during sustained contraction after eccentric exercise. Med Sci Sports Exerc, 2009, 41: 1927–1933. [Medline] [CrossRef]
10) Pereira R, Schettino L, Machado M, et al.: Task failure during standing heel raises is associated with increased power from 13 to 50 Hz in the activation of triceps surae. Eur J Appl Physiol, 2010, 110: 255–265. [Medline] [CrossRef]
11) Hedayatpour N, Hassanlouei H, Arendt-Nielsen L, et al.: Delayed-onset muscle soreness alters the response to postural perturbations. Med Sci Sports Exerc, 2011, 43: 1000–1006. [Medline] [CrossRef]
12) Riemann BL, Limbaugh GK, Eitner JD, et al.: Medial and lateral gastrocnemius activation differences during heel-raise exercise with three different foot positions. J Strength Cond Res, 2011, 25: 634–639. [Medline] [CrossRef]
13) Clement DB, Taunton JE, Smart GW: Achilles tendinitis and peritendinitis: etiology and treatment. Am J Sports Med, 1984, 12: 179–184. [Medline] [CrossRef]
14) Whitting JW, Steele JR, McGhee DE, et al.: Dorsiflexion capacity affects Achilles tendon loading during drop landings. Med Sci Sports Exerc, 2011, 43: 706–713. [Medline] [CrossRef]
15) Arya S, Kulig K: Tendinopathy alters mechanical and material properties of the Achilles tendon. J Appl Physiol 1985, 2005, 108: 670–675. [Medline] [CrossRef]
16) Azvedo LB, Lambert MI, Vaughan CL, et al.: Biomechanical variables associated with Achilles tendinopathy in runners. Br J Sports Med, 2009, 43: 288–292. [Medline] [CrossRef]