



Original Article

Therapeutic effects of massage and electrotherapy on muscle tone, stiffness and muscle contraction following gastrocnemius muscle fatigue

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Abstract. [Purpose] This study aimed to examine the effects of a combined intervention consisting of massage therapy and transcutaneous electrical nerve stimulation on gastrocnemius muscle fatigue, assessing whether the intervention improved muscle tone, stiffness, and muscle contraction. [Subjects and Methods] The subjects were 20 healthy males in their 20s who were equally divided into a transcutaneous electrical nerve stimulation group and a combined therapy group that received a combination of massage therapy and transcutaneous electrical nerve stimulation. Muscle fatigue was triggered on the gastrocnemius muscle, and the effects of intervention method on muscle tone, stiffness, and muscle contraction were examined over time. [Results] Lateral and medial gastrocnemius muscle tone and stiffness significantly increased and gastrocnemius muscle contraction significantly decreased in each group immediately after fatigue was triggered on the gastrocnemius muscle. There was no difference in the effects of the two intervention methods over time. [Conclusion] This study verified that a combined therapy of massage therapy and transcutaneous electrical nerve stimulation was able to be used effectively in improving muscle tone, stiffness, muscle contraction, thereby reducing gastrocnemius muscle fatigue.

Key words: Muscle fatigue, Muscle tone, Stiffness

(This article was submitted Jul. 15, 2016, and was accepted Oct. 18, 2016)

INTRODUCTION

Muscle fatigue triggers a decrease in the skin's sensory faculty¹⁾, an accumulation of metabolites within muscle fibers, and inadequate motor command in the motor cortex²⁾. Musculoskeletal disorders change muscle tone and stiffness of the body³⁾, and abnormal muscle tone may cause muscle damage⁴⁾. Therefore, muscle fatigue should be appropriately managed in order to prevent these negative outcomes.

Massage therapy is one widely used therapeutic intervention⁵⁾ that is effective for recovering from pain, muscle stiffness, perceived fatigue, and fibromyalgia^{5, 6)}. Transcutaneous electrical nerve stimulation (TENS) is also effective for decreasing muscle fatigue⁷⁾ and enhancing postural sway⁸⁾. Recently, some studies have reported that electrical stimulation has an positive effect on the management of muscle fatigue^{7, 8)}, but a greater effect was reported with the use of therapies that combined different interventions^{9, 10)}.

There is not much research on the effects of muscle fatigue on muscle tone and stiffness of the body and the effects of various interventions on muscle fatigue. Accordingly, this study intended to examine the effects of a combined intervention of massage therapy and TENS on the improvement of gastrocnemius (GCM) muscle tone, stiffness, and muscle contraction.

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SUBJECTS AND METHODS

This study randomly and equally divided 20 healthy males residing in a local community into a TENS group that employed only TENS (mean \pm SD: age, 22.0 ± 1.6 years; height, 178.0 ± 7.9 cm; body weight, 74.8 ± 12.5 kg) and a combined therapy (CT) group that employed both massage therapy and TENS (mean \pm SD: age, 22.7 ± 1.4 years; height, 173.5 ± 4.2 cm; body weight, 66.4 ± 7.1 kg). Those who had a musculoskeletal or neurological disorder, had regularly exercised within the past three months, or had conducted strengthening or aerobic exercises within the past five days were excluded from this study. All the subjects sufficiently listened to and agreed with the purpose and purport of this study. This study was conducted with the approval of Howon University's Life Ethics Committee and all subjects signed an informed consent of the study.

Muscle fatigue was induced by having each participant maximally and continuously conduct a calf raise with his ankle plantar flexion on a stool (which had a height of 20 cm) with his dominant leg's GCM muscle as the subject until he was no longer able to raise his calf⁸⁾.

After muscle fatigue was triggered in each subject, an intervention was applied to each group once per day for two days for 15 minutes each day. The calf region of each subject in the TENS group was stimulated with two channels using an electrostimulator (TENS-7000, Koalaty Products Inc., USA) with a frequency of 100 Hz, a pulse duration of 200 μ s⁸⁾, and an adhesive electrode with a diameter of two inches (Nurostimulation Electrodes, ValuTrode, USA). Massage therapy¹¹⁾ was applied to the lateral and medial GCM muscles of each subject in the CT group for seven minutes, and massage therapy and TENS were applied to the lateral and medial GCM muscles of each subject in the TENS group for seven minutes and eight minutes, respectively. The intensity of the TENS was adjusted according to each subject's tolerance. All the interventions of this study were applied while each subject was in a prone position.

Lateral and medial GCM muscle tone and stiffness were measured in a prone position using Myoton[®]PRO (MyotonAS, Estonia). A mark was placed symmetrically on the highest muscle belly, and measurement equipment was placed vertically³⁾. An average value of two measurements was used as data. For the measurement of the maximal voluntary muscle contraction of the GCM muscle, a Commander PowerTrack II Muscle Tester (JTECH Medical, Inc. USA), which is a handheld dynamometer, was used. Each subject extended his knees while in a prone position on the plinth and maximally dorsiflexed his plantar, at which point a measurement was taken¹²⁾. In order to prevent muscle fatigue recovery during these repetitive measurements after muscle fatigue was induced, a measurement was taken once after two practice measurements. Measurements were taken four times: before the inducement of muscle fatigue, immediately after the inducement of muscle fatigue, after the application of the intervention on the first day (24h), and after the application of the intervention on the second day (48h).

The measured indoor temperature was 23 °C. All the interventions and measurements was applied by a physical therapist who had completed a Maitland Level IIA course. All the data collected from this study were analyzed using a statistical processing program (SPSS 210/PC, USA).

RESULTS

Each subject in each group's muscle tone, stiffness, and muscle contraction before and after the inducement of muscle fatigue was the same and there was no significant difference. A repeated measure analysis of variance (ANOVA) test was conducted to assess changes in muscle tone, stiffness, and muscle contraction before and after the inducement of muscle fatigue in each group, and as a post hoc test, a simple and repeated contrast test was carried out. An independent t-test was conducted in order to compare the changes between the two groups. The significance level was set at $\alpha=0.05$. According to the results of the repeated measure ANOVA analysis, each group's GCM muscle tone and stiffness significantly increased and their GCM muscle contraction significantly decreased immediately after the inducement of muscle fatigue ($p<0.05$). GCM muscle tone and stiffness significantly decreased and muscle contraction significantly increased in both the TENS and CT groups one day after the intervention ($p<0.05$). Two days after the intervention, both groups' GCM muscle tone and stiffness decreased and muscle contraction increased, but lateral GCM muscle tone and stiffness significantly decreased only in the TENS group ($p<0.05$). There was no significant difference in the improvement effects of each group over time (Table 1).

DISCUSSION

In this study, both the TENS group and the CT group saw lateral and medial GCM muscle tone and stiffness significantly increase immediately after the inducement of muscle fatigue and significantly decrease after the application of the intervention for one day. After one day, there was no significant difference in the changes in muscle tone and stiffness of the GCM muscle between the two groups, but on average, the CT group showed a greater decrease.

Such a result is noteworthy because massage therapy decreases alpha and beta activity, inducing a relaxation response⁵⁾, which more greatly influences a decrease in muscle tone and stiffness. In a previous study, Kang et al.¹³⁾ reported that TENS did not have obvious effect on recovery from erector muscle fatigue. Since the intervention effect of TENS on muscle fatigue recovery may differ according to different body parts, the application of massage therapy together with TENS will be effective.

Table 1. Change in muscle tone, stiffness and muscle contraction on each group

Region	Variable	Group	Pre-fatigue	Post-fatigue	1 Day	2 Day
Lateral gastrocnemius muscle	Muscle tone (Hz)	TENS	17.4 ± 0.3	19.5 ± 0.8*	17.8 ± 0.3 [†]	15.9 ± 0.8 [‡]
		CT	18.3 ± 0.3	19.7 ± 0.5*	17.4 ± 0.4 [†]	17.4 ± 0.4
	Stiffness (N/m)	TENS	323.3 ± 8.8	377.1 ± 12.7*	317.6 ± 6.3 [†]	306.7 ± 4.9 [‡]
		CT	320.6 ± 8.3	371.5 ± 15.7*	296.0 ± 7.9 [†]	294.1 ± 9.2
Medial gastrocnemius muscle	Muscle tone (Hz)	TENS	16.8 ± 0.2	18.6 ± 0.3*	16.1 ± 0.1 [†]	15.6 ± 0.8
		CT	17.8 ± 0.4	19.4 ± 0.5*	17.1 ± 0.5 [†]	17.1 ± 0.4
	Stiffness (N/m)	TENS	297.8 ± 6.9	358.8 ± 6.7*	293.6 ± 3.8 [†]	292.6 ± 4.6
		CT	302.1 ± 9.0	368.7 ± 14.6*	287.0 ± 8.6 [†]	284.2 ± 6.0
Gastrocnemius muscle contraction (N)	TENS	245.5 ± 4.1	201.1 ± 3.8*	237.9 ± 5.2 [†]	245.2 ± 3.8	
	CT	251.0 ± 5.6	211.8 ± 7.7*	243.5 ± 4.1 [†]	247.3 ± 5.1	

Values are means ± SE.

TENS: transcutaneous electrical nerve stimulation group, CT group: Combined therapy group

*Significant difference between pre-fatigue and post-fatigue, [†]Significant difference between post-fatigue and 1day, [‡]Significant difference between 1 day and 2 day

tive for the management of muscle fatigue. Two days after the intervention, only the muscle tone and stiffness of the lateral GCM muscle of the TENS group significantly decreased, but there was no significant difference in the amount of change between the two groups.

In this study, both groups' GCM muscle contraction significantly decreased immediately after the induction of muscle fatigue but significantly increased after intervention was applied for one day. However, there was no significant difference between the study groups, and the subjects' natural physical recovery ability likely had an effect because the subjects were young adults in their 20s. Cho et al.⁸⁾ saw muscle contraction decrease immediately after the inducement of GCM muscle fatigue, but their findings support the present study's results by verifying that the application of TENS had a significant effect on the recovery of muscle contraction ability.

At present, as an intervention method for fibromyalgia, a combined therapy using electrical therapy methods has been presented as a better treatment than a single therapy^{9, 10)}. In this study, when TENS was applied to GCM muscles in which muscle fatigue had been triggered, muscle tone and stiffness decreased on average when TENS and massage therapy were applied in combination. This result suggests that for the management of muscle fatigue and delayed onset muscle soreness, using different intervention methods should be preferred over the employment a single intervention method. A limitation of this study, the findings cannot be generalized to women or neurological disorder, because the subjects were in healthy male.

However, this study verified that a combined therapy of TENS and massage therapy may be an effective intervention for the recovery of GCM muscle tone and stiffness.

ACKNOWLEDGEMENT

Funding of this paper was provided by Howon University.

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