Effect of Static Stretching Using Foot Stretching Device in the Elderly: An Interim Report

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***Abstract*—The exerciser "Relegs," a home-use rehabilitation device, was modified such that static stretching could be performed. In this study, the effect of static stretching for foot using the modified device was evaluated in twelve healthy elderly people. After stretching, the passive dorsiflexion angle of the foot increased significantly and the stretched length of the medial head of the gastrocnemius muscle which was evaluated using an ultrasound imaging device shortened significantly. This indicated that the flexibility of the soft tissues other than muscles might have been improved by static stretching using an automated foot stretching machine in the elderly.**

Keywords—rehabilitation device, static stretching, ankle joint, stiffness, muscle tendon junction

I. Introduction

Static stretching is frequently used as a treatment for decreased range of motion and increased muscle tone of the foot. In clinical practice, stretching is performed manually [1, 2]; however, thus far, several pieces of equipment have been studied to automate foot stretching [3–8], although there are no commercially available ones. Some of them simulate the three-dimensional manual stretching [7, 8] whereas the majority of them have one degree-of-freedom motion of dorsi/planter flexion. Most of these are large and unsuitable for home use. In addition, most studies have targeted healthy young people and stroke survivors, so their effect on the elderly is not clear.

The exerciser, "Relegs" (LAP, Co., Ltd., Japan), is a commercial device for home rehabilitation. Risk reduction of Relegs for single failures is achieved relatively easily because its driving mechanism is based on a pneumatic actuator. The bellows connected to the part on which the foot is placed expands due to the inflow of air, and the foot is dorsiflexed (Fig. 1). If the flow of air is stopped, the foot can return to the initial position slowly. This device was developed to exercise lower limb muscles continuously at home, but it only performs repeated plantarflexion and dorsiflexion. Therefore, we modified the exerciser such that static stretching could be performed [9, 10]. The effectiveness of foot stretching using the modified device in young healthy people has already been shown [10, 11]. However, it has not been clarified which tissue was stretched. So, in the present study, we focused on changes in the stiffness of the stretched muscles. Some previous studies investigated the effect of stretching on muscle stiffness by measuring the muscle tendon of the foot [12, 13]. Therefore, whether the stiffness of muscles changes before or after foot stretching using a modified stretching device was investigated using ultrasound imaging.

This work was supported by JSPS KAKENHI Grant Number 17K13108 and 20K19403 and Grants-in-Aid for individual research in Aichi Medical College. We also acknowledge technical supports from LAP Co, Ltd.

II. Method

A. Participants

Twelve healthy elderly people (five men and seven women, 73.2 ± 3.8 years old) (mean ± standard deviation) participated. They had no foot disorders or pain. All participants provided informed consent before the experiment. This study was approved by the Ethics Committee of Aichi Medical College for Physical and Occupational Therapy.

B. Protocols

An experiment was conducted on the right foot with dorsiflexion stretching using the modified device. The target muscles for stretching were the gastrocnemius and soleus muscles. The stretching outcomes were measured before and after stretching.

Static stretching was performed in the sitting position with the knee extended and the right leg on the stretching device (Fig. 2). For safety, this device has a mechanism that is driven only while the user is pressing the switch. Therefore, all operations were performed with the subject pressing the switch. Before performing stretching, the subject held the switch while the foot was dorsiflexed by the stretching device to an angle at which he or she felt stretched. This angle was set as the maximum dorsiflexion angle during stretching for

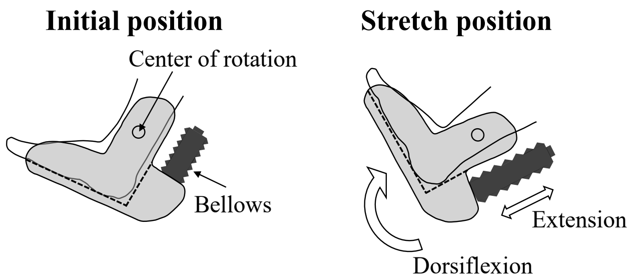

Fig. 1. Operation principle of stretching device.

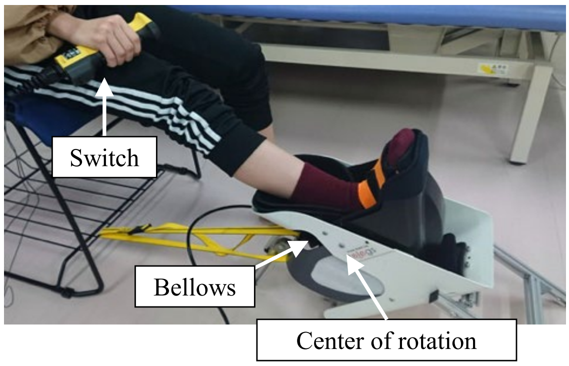

Fig. 2. Situation of static stretching using the device.

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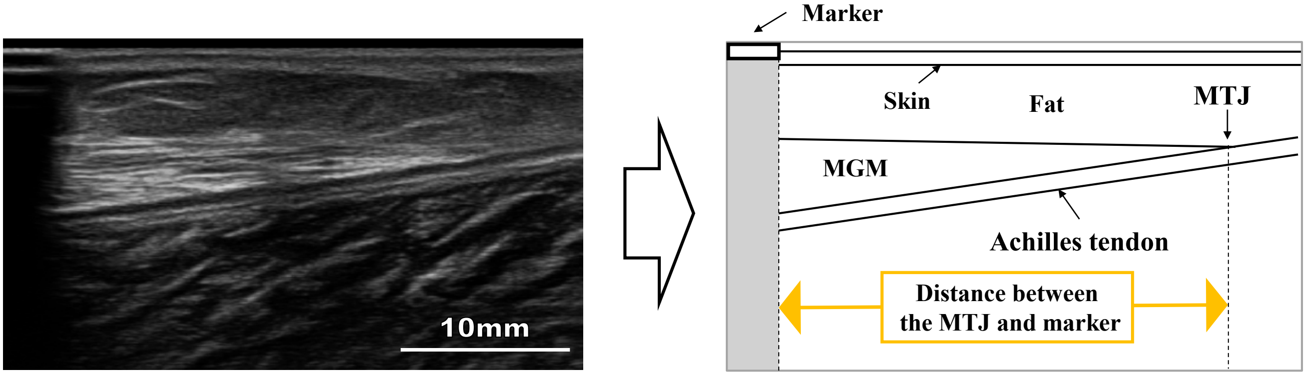

Fig. 3. Left; Image of ultrasonography. Right; Method to measure of the distance between the MTJ and marker in order to identify the stretched length of the MGM.

TABLE I. RESULTS OF THE DORSIFLEXION ANGLE AND THE STRETCHED LENGTH OF THE MGM

	Dorsiflexion angle (°)		Stretched length of MGM (standardized data)				
			0°	5°	10°	15°	
Pre	18.3 ± 5.0	*	−2.8 ± 5.6	−1.6 ± 9.6	0.1 ± 14.6	1.0 ± 17.0	+
Post	24.1 ± 6.1		−6.1 ± 11.5	−2.9 ± 6.2	−1.4 ± 5.0	−1.0 ± 9.7	#

average ± standard deviation
*: $p < 0.01$ for pre vs post in *t*-test
+: $p < 0.01$ for pre vs post in two-way analysis of variance
#: $p < 0.01$ for measurement angle in two-way analysis of variance

each subject. Two minutes of static stretching was performed using the device at this dorsiflexion angle. This was repeated for five sets, with the maximum dorsiflexion angle set each time. In total, static stretching was performed for ten min in one experiment. It took ~30 s to set the angle between sets.

C. Outcome measure

To investigate the stretching effect, the passive dorsiflexion angle of the foot and the stretched length of the medial head of the gastrocnemius muscle (MGM) was measured. Each measurement was performed in the supine position with the knee at 30° flexion. The dorsiflexion angle was measured manually using a goniometer. The stretched length of the MGM was evaluated using an ultrasonic diagnostic imaging device (ARIETTA Prologue, Hitachi, Co., Ltd, Japan). With reference to the method of Morse et al. [12], in order to define the stretched length of the MGM, the muscle tendon junction (MTJ) of the MGM was identified using the ultrasound imaging device before measurement. An acoustic reflection marker was attached to the skin near the MTJ of the subject, and the probe of the ultrasound imaging device was placed so that the marker and MTJ could be viewed at the same time. The marker was attached to the exact same place in the evaluation before and after stretching. The images were taken using an ultrasound imaging system while the subject's foot was passively dorsiflexed from 0° to 15° in 5° increments. Image processing software (Image J, National Institute of Health, USA) was used to calculate the length from the acoustic reflection marker to the MTJ at each angle. The change in the distance between the MTJ and marker for each angle was defined as the stretched length of the MGM (Fig. 3).

D. Data analysis

The dorsiflexion angles before and after stretching were compared using a paired *t*-test. The length of the extended MGM was standardized to eliminate individual differences among subjects, and the average value of each subject was set to 0 by subtracting each data value from the average value of all data before and after stretching within each subject. Subsequently, two-way analysis of variance was performed using two factors, "pre- and post-stretching" and "measurement angle." The significance level was set at $p < 0.05$.

III. RESULTS

The results are shown in Table I. The dorsiflexion angle significantly increased from 18.3 ± 5.0° before to 24.1 ± 6.1° after stretching ($t(11) = 2.20$, $p < 0.001$). The stretched length of the MGM was analyzed in seven people, excluding subjects whose passive dorsiflexion angle did not reach 15° during measurement. The two-way analysis of variance identified that the stretched length of the MGM significantly decreased after stretching ($F(1,5) = 3.90$, $p < 0.001$). There was also a significant difference between the measurement angle ($F(3,5) = 2.66$, $p < 0.001$), while there was no significant interaction ($p = 0.45$).

IV. CONCLUSION AND DISCUSSION

In this study, the effects of the foot stretching device for healthy elderly people were investigated. As a result, the dorsiflexion ROM significantly increased and the stretched length of the MGM significantly decreased after stretching.

In our previous study of healthy young people [10], stretching with the device reduced the resistance torque of the ankle joint during passive dorsiflexion. This indicated that the ankle stiffness had decreased. Some previous studies investigating the effect of stretching by measuring the MTJ reported that the displacement of the MTJ increased; that is, the muscle stiffness of the foot decreased [12, 13]. In this study, while we focused on the length of the MGM and evaluated the change in the displacement of the MTJ before and after stretching using an ultrasonic imaging system, the length decreased after stretching. In other words, by static stretching using the device, tissues other than the gastrocnemius muscle was stretched so that the dorsiflexion angle increased. Kubo et al. [14] and Kato et al. [15] reported that static stretching for 10 to 20 min decreased tendon stiffness over muscle stiffness. The present study performed 10-min stretching totally for each subject. Therefore, the tendon stiffness might have decreased due to continued proper stretching by the device. That is, the foot stretching device might have improved the flexibility of the soft tissues, such as the Achilles tendon and joint capsule.

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