Archives of Physical Health and Sports Medicine

ISSN: 2639-1805

Volume 3, Issue 1, 2020, PP: 01-06

Analysis of the Effects of Static Stretching of the Ankle on Joint Drive Resistance Based on Joint Movement Direction and Exercise Area

Shigeru Terada*, Masahiro Goto, Yoshihiro Yamashina, Hiroto Honda, Yosuke Yamato, Tomoko Hirayama

Department of physical therapy, Faculty of Health Science, Aino University, Japan.

s-terada@pt-u.aino.ac.jp

***Corresponding Author:** Shigeru Terada, Department of physical therapy, Faculty of Health Science, Aino University, Japan.*

Abstract

The purpose of this study was to examine the effect of static stretching on the plantar flexor muscles of the ankle joint on bilateral resistance to plantar flexion and dorsiflexion. The subjects included 25 healthy men. Ankle dorsiflexion and plantar flexion were passively performed before and after static stretching, and a muscle tonus electromyograph was used to measure the ankle joint's passive resistance. The spring coefficient was measured as the slope of the angle-torque regression line at the time of passive movement and was compared for the total, proximal, and distal ranges of motion. The dorsiflexion spring coefficient decreased in all angles after stretching, and significant differences were observed in the total and distal ranges of motion. The plantar flexion spring coefficient decreased after stretching in all items, and a significant difference was observed in the total range of motion. The rates of decrease in all excursions were 15.7% and 10.5% for the dorsiflexion and plantar flexion spring coefficients, respectively, with the former showing a higher rate of change. The results suggest that dorsiflexion static stretching for ankle joints may reduce joint drive resistance not only in the dorsiflexion direction but also in the plantar flexion direction.

Keywords: *static stretching, ankle joint, dorsiflexion, plantarflexion, spring coefficient*

Introduction

Walking, which is a major means of transportation, is an important ability for performing activities of daily living . For this reason, walking difficulty is a major problem seen in the physical therapy setting. Walking requires that the standing position is stable as a pre-walking stage.

The ankle joint plays an important role in maintaining standing posture. When standing, the joints are asymptotically stabilized by the elasticity of the muscles, as determined by the tonus of the plantar flexor and dorsiflexors of the ankle joint and the high rigidity of the Achilles tendon. This is called the stiffness control hypothesis of the standing posture [1].

Increases and decreases of muscle tonus are regarded as changes in the driven resistance of the joint [2]. Joint stiffness refers to limited range of motion, decreased muscle extensibility, increased muscle tone and muscle stiffness, and skin stiffness due to scarring [3]. Joint stiffness is known to change with exercise history and has been reported to be reduced by various stretching methods [4,5].

Changes in joint stiffness have various effects on performance of the motion. For example, joint stiffness is increased in patients with joint contracture due to disuse, fixation or immobility, and spasticity associated with central nervous system disorders, which may result in movement disorders and reduced efficiency [6,7]. Conversely, there is a report that a decrease in joint stiffness results in an increase in energy loss on the sports field [8], resulting in a decrease in power transmission efficiency and performance. Mobility and fixation of joints are opposing factors. Therefore, it is important to know the state of joint stiffness and to understand its change when considering the rehabilitation treatment policies and when selecting treatment techniques and evaluating treatment effects.

This time, we examined how joint stiffness changes due to static stretching, which is frequently used in clinical practice. Although there are many previous studies on static stretching, most of them are tests only on the direction of joint movement related to the muscle to be stretched. For example, it is reported that when the triceps surae is stretched at the ankle joint, the joint stiffness in the dorsiflexion direction is reduced, but the effect on the dorsiflexors and the tissue of the anterior part of the lower leg that are held for a certain period in the shortened direction has not been confirmed. Therefore, in this experiment we examined the effects of stretching for both plantar flexion and dorsiflexion and obtained useful information for developing a rehabilitation program.

Materials and Methods

The subjects were 25 healthy men with no history of neuropathy or osteoarthritis in the lower limbs. The subjects' age, height, weight, and BMI were 30.7 ± 9.1 years, 168.3 ± 2.3 cm, 64.2 ± 6.3 kg, and 23.3 ± 2.5 (mean ± standard deviation), respectively. The sample size using paired t-test with G* Power 3.1 (Institute for Experimental Psychology at Heinrich Heine University Dusseldorf, Dusseldorf, Germany), with detection power of 0.95, Cohen's effect size of 0.8, and significance level of 0.05.

Before the study started, we explained verbally and in writing to all subjects the purpose and scope of the research, that all obtained data will not be used for other purposes, and that personal information will be strictly managed and kept confidential. They also understood that participation in the study was voluntary, and all subjects signed the consent form after understanding the scope of the study. This study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Research Ethics Committee of Aino University (Aino2019-01).

Using a muscle tonus electromyograph (MTM-06 Muscle Master; Medicalnics, Osaka, Japan) that measures both joint angle and torque simultaneously with a load cell and gyro sensor, the right leg joint movement resistance of the subject was measured, followed by the measurement of the right foot joint resistance. First, measurements were taken before the stretching intervention. The limb position during the measurement was in prone position on the right side of the bed, with the knee joint of the measurement limb in full extension and the lower leg extended from the end of the bed. After 2 minutes of rest, passive exercises in the plantar flexion and dorsiflexion directions were performed three times at the ankle joint to relax, and 1 minute later, measurements were made during exercise in the same direction. The starting position was maximum dorsiflexion position of the ankle joint, and the sensor unit was sandwiched and fixed (Figure 1). Simultaneously, the part of foot back was marked so that it could be identified even after stretching. The ankle joint was passively moved from the maximum dorsiflexion to the maximum plantar flexion according to the instructions on the assist screen of the device. The exercise speed was synchronized with the moving image shown on the monitor of the device, and the exercise was performed at a rhythm of 5 times per minute. The measured data were obtained using the regression line of the angle-torque characteristic plot during passive motion, $y = Kfx + b$ slope kf (Nm/rad), as the elastic coefficient. The spring coefficient was calculated in both dorsiflexion and plantar flexion directions. The calculation was performed in the following ranges, with the exclusion of the initial and final 10⍰: total range of motion, first half (proximal) of the range, and second half (distal) of the range. The intervention method involved standing on a device capable of holding the ankle joint at 20⍰ and stretching the ankle plantar flexor muscle group by load, during which the knees were fully extended and the back was in contact with the wall in order to prevent variations in the forward leaning of the trunk.

Fig 1. *Measurement equipment and conditions.*

According to previous studies, the intervention protocol differed in stretch time from 20 to 150 seconds and the number of sets ranged from 4 to 10 times [9-12]. Based on the report of Morse et al. [12], one set of continuous stretch for 1 minute and rest for 30 seconds was repeated 5 times. At the time of stretching, all subjects felt a sense of stretch of the triceps surae, but the stretch was almost lost in the final fifth set. Immediately after the intervention task, joint resistance was measured again and measurements were compared to those obtained before stretching. We periodically checked for any muscle activity from the gastrocnemius that could affect drive resistance using an electromyogram.

Statistical analysis was performed using SPSS Statistics version 20 (IBM Corp., Armonk, NY, USA). First, a normality test was performed using the Shapiro-Wilk test, and the normal distribution of all data was confirmed. Data were analyzed by paired t-test, and the significance level was set to < 5%.

Results

The data sample is shown in Figure 2.

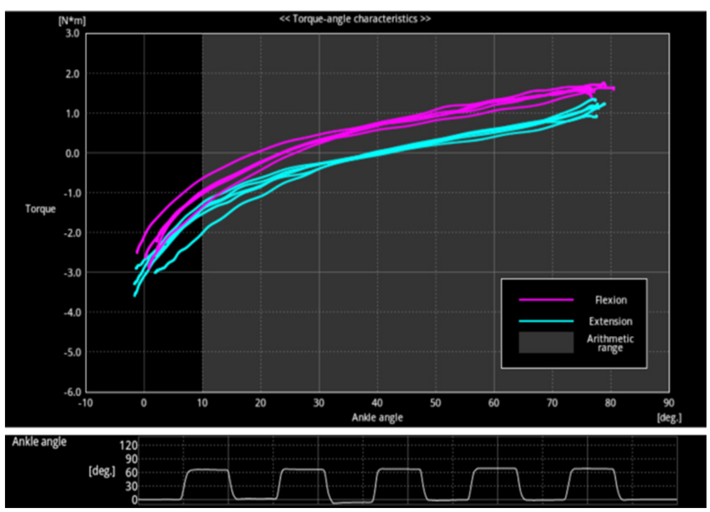

Fig 2. *Measurement data: The upper row shows the angle-torque curve during passive movement of the ankle joint. The lower row shows changes in the ankle angle.*

Table 1 shows the dorsiflexion spring coefficients before and after stretching. After stretching, the dorsiflexion spring coefficient decreased in all items. A significant difference was observed in the total and distal range of motion.

Table 1. *Comparison of the dorsiflexion spring coefficients before and after stretching.*

Dorsiflexion spring coefficient

	Before intervention	After intervention	P value
Total range of motion (Nm/rad⍰	2.49 ± 0.82	2.10 ± 0.11	0.001
Proximal⍰Nm/rad⍰	2.02 ± 0.36	1.97 ± 0.25	0.867
Distal⍰Nm/rad⍰	2.62 ± 0.11	2.26 ± 0.10	0.003

Table 2 shows the changes in the plantar flexion spring coefficient. Similar to the dorsiflexion spring coefficient, the joint drive resistance decreased after stretching in all portions of the range of motion, and a significant difference was observed in the entire range of motion. The rate of decrease in spring coefficient in the total range of motion was 15.7% for dorsiflexion and 10.5% for plantar flexion, indicating a high rate of change in dorsiflexion.

Table 2. *Comparison of the plantar flexion spring coefficients before and after stretching.*

Plantar flexion spring coefficient

	Before intervention	After intervention	P value
Total range of motion (Nm/rad⍰	2.38±0.13	2.13±0.11	0.001
Proximal⍰Nm/rad⍰	3.16±0.39	2.75±0.31	0.158
Distal⍰Nm/rad⍰	2.48±0.14	2.33±0.11	0.135

The correlation coefficient of the spring coefficient before and after stretching was 0.69 to 0.85 for all six pairs. In the total range of motion, the correlation coefficients for dorsiflexion and plantar flexions were 0.80 and 0.85, respectively, indicating high correlation.

Discussion

We evaluated the effect of static stretching of the ankle joint on joint drive resistance using a muscle tonus electromyograph. We found a decrease in the spring coefficient in the total range of motion in the dorsiflexion direction, and the amount of change was greater than that in the plantar flexion direction. This means that the stiffness of the muscle-tendon unit of the ankle plantar flexor decreased. Regarding the decrease in stiffness in the dorsiflexion direction, the results supported the reports of Morse et al. [12] and Ryan et al. [13] that joint passive torque decreased due to the stretching of the triceps muscle of the calf. Gajdosik et al. [14] suggest that muscle stiffness may be reduced by altering fascia flexibility and gliding properties. In addition, according to Morse et al. [12] and Herda et al. [15], Golgi tendon organs, which are thought to be present at the transition between muscle and tendon, become excited and propagate the signal to type Ib fibers, which enters the dorsal horn of the spinal cord and suppresses the muscle tone of the homonymous muscles. This suggests that changes occurred in the viscoelasticity of the entire muscle-tendon unit. However, as for the immediate effect of stretching on the muscle-tendon unit, there is no unified view such as reports of decreased passive torque [12-16] and stiffness or increase in range of motion without any change in passive torque or stiffness [17,18]. This appears to be due to factors such as the stretch task method and differences in the muscles and measurement data in each study; however, in this study, the spring coefficient was divided into total, proximal, and distal ranges of motion. As a result, there was a significant decrease in the total range of motion in the dorsiflexion direction; however, there was no significant difference between the proximal and distal ranges of motion. This result suggests that there may be different results depending on the angle of the measured joint motion used to obtain the regression equation. Because the degrees of muscle extension and tension of the joint tissues differ among the starting, intermediate, and final stage of joint motion, detailed data in each angle range for various joints should be collected.

In this study, decreases in the total range of motion and the distal spring coefficient were observed in both the plantar flexion and dorsiflexion directions. This time, the triceps muscle of the calf was used as the target muscle for stretch; thus, the passive torque of the joint decreased even in the opposite movement direction. In previous studies, only the change in passive torque in the direction of movement related to the extension muscles (dorsiflexion direction in this experiment) was examined; however, this result suggests that the passive resistance of the joint decreases, even in the shortening direction of the target muscle. During ankle dorsiflexion stretching, the skin and subcutaneous tissues of the foot and anterior part of the lower leg are maintained in a “deflected” state. The intervention method used in this study was 5 sets of 1-minute stretch and 30-second rest, and this repetition clearly caused changes in the thixotropy of the skin and connective tissue and contributed to the decrease in passive resistance. In particular, in the distal plantar flexion region, the final limb position is the maximum plantar flexion position and the skin and subcutaneous tissues of the foot and anterior part of the lower leg are greatly stretched. Fukui [19] reported that skin movement affected joint movement. It states that the tension line when the skin is stretched in the final range of motion of the joint is important. Elements constituting the driven resistance of the joint are classified into contractile elements, tendons, and non-contractive elements such as the skin, joint capsules, and ligaments. Regarding the decrease in the spring coefficient in the distal region, it has been suggested that the driven resistance of antagonistic muscles other than the stretched muscles affects the joint torque, and that some changes in other joint components occurred. In this study, the effect of dorsiflexion and plantar flexion was confirmed by dorsiflexion stretching of the ankle joint. However, histological and electrophysiological studies have not been performed, and further studies are needed in the future. These findings suggest that in a rehabilitation approach to a patient with limited range of motion of the ankle, stretching interventions reduce bi-directional drive resistance and thereby increase joint mobility. However, we need to be aware that this condition can lead to decreased joint fixation.

Conclusion

Changes in joint stiffness after static stretching of the ankle joint were examined in healthy subjects. As a result, the joint drive resistance during the passive movement decreased for both dorsiflexion and plantarflexion. In addition, our results suggest that the driven resistance may be different at the start, middle, and end of the range of motion according to the direction of motion. Treatment programs should be carried out while considering the opposing elements of joint mobility and joint fixation.

References

[1] WinterD.A, PatlaA.E, PrinceF, et al. Stiffness control of balance in quiet standing. J Neurophysiol 1998;80:1211-1221.

[2] BohannonR.W, SmithM.B. Interrater reliability of a modified Ashworth scale of muscle spasticity. Phys Ther1987; 67: 206-207.

[3] Muraki, T. Assessment of skeletal muscle and joint with stiffness measurement. Phys Ther Japan 2010 ;37:654-657.

[4] NordezA, Comu C, McNairP. Acute effects of stretching on passive stiffness of hamstring muscle calculated using different mathematical models. Clinical Biomech 2006;21: 755-760.

[5] Nordez A, McNairP.J, CasariP, et al. Static and cyclic stretching: their different effects on the passive torque-angle curve. J Sci Med Sport 2010;13: 156-160.

[6] LamontagneA, Malouin F, RichardsC. Contribution of passive stiffness to ankle plantar flexor moment during gait after stroke. Arch of Phys Med Rehabil 2000;81: 351-358.

[7] SinkjairT, MagnussenI. Passive intrinsic and reflex-mediated stiffness in ankle extensors of hemiparetic patients. Brain 1994;117: 355-363.

[8] Fowles J.R, Sale D.G, MacDougallJ.D. Reduced strength after passive stretch of the human plantarflexors. J Appl Physiol 2000; 89: 1179-1188.

[9] Ryan E.D, HerdaT.J, CostaP.B, Defreitas J.M, BeckT.W, StoutJ, CramerJ.T. Determining the minimum number of passive stretches necessary to alter musclotendinous stiffness. J Sports Sci 2009;27: 957–961.

[10] NordezA, GennissonJ.L, Casari, P, CathelineS, Cornu, C. Characterization of muscle belly elastic properties during passive stretching using transient elastography. J Biomech 2008; 41: 2305–2311.

[11] HalbertsmaJ.P, Van BolhuisA.I, GöekenL.N. Sport stretching: effect on passive muscle stiffness of short hamstrings. Arch Phys Med Rehabil 1996;77: 688–692.

[12] MorseC.L, DegensH, SeynnesO.R, MaganarisC.N, Jones D.A. The acute effect of stretching on the passive stiffness of the human gastrocnemius muscle tendon unit. J Physiol 2008;586: 97–106.

[13] Ryan E.D, BeckT.W, HerdaT.J, HullH.R, Hartman M.J, Costa P.B, DefreitasJ.M ,Stout J.R, Cramer J.T. The time course of musclotendinous stiffness responses following different durations of passive stretching. J Orthop Sports Phys Ther 2008; 38: 632–639.

[14] Gajdosik R.L. Passive extensibility of skeletal muscle: review of the literature with clinical implications. Clin Biomech 2001; 16: 87–101.

[15] HerdaT.J, Costa P.B, Walter A.A, Ryan E.D, Hoge K.M, Kerksick C.M, Stout J.R, Cramer J.T. Effects of two modes of static stretching on muscle strength and stiffness. Med Sci Sports Exerc 2011; 43: 1777–1784.

[16] Magnusson S.P, Simonsen E.B, Aagaard P,Kjaer M. Biomechanical responses to repeated stretches in human hamstring muscle in vivo. Am J Sports Med 1996; 24: 622–628.

[17] Muir I.W,Chesworth B.M,Vandervoort A.A. Effect of a static calf-stretching exercise on the resistive torque during passive ankle dorsiflexion in healthy subjects. J Orthop Sports Phys Ther 1999; 29: 106–113.

[18] McNair P.J,Dombroski E.W, Hewson D.J, Stanley S.N. Stretching at the ankle joint: viscoelastic responses to holds and continuous passive motion. Med Sci Sports Exerc 2001; 33: 354–358.

[19] Fukui T. Skin Kinesiology for Physical Therapy. Phys Ther Japan 2011; 38: 337-340.

Citation: **Shigeru Terada, Masahiro Goto, Yoshihiro Yamashina, Hiroto Honda, Yosuke Yamato, Tomoko Hirayama.** *Analysis of the Effects of Static Stretching of the Ankle on Joint Drive Resistance Based on Joint Movement Direction and Exercise Area. Archives of Physical Health and Sports Medicine. 2020 3(1): 01-06.*

Copyright: © *2020* **Shigeru Terada, Masahiro Goto, Yoshihiro Yamashina, Hiroto Honda, Yosuke Yamato, Tomoko Hirayama.** *This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.*