Effect of stretch on improvement of muscular contractures in rats

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Abstract. [Purpose] The purpose of this study was to investigate how a stretching torque affects muscular contractures. [Subjects] The subjects of this study were 48 male Wistar rats. [Methods] Subjects were divided into 4 groups as follows: Group 1 was the control; Group 2 had muscles in continuous fixation; Group 3 had muscles stretched in the direction of dorsiflexion by a spring balancer set at a torque of 0.3N for a period of 30 minutes after continuous fixation; and Group 4 had muscles stretched in the direction of dorsiflexion by a spring balancer set at a torque of 3.0N for a period of 30 minutes after continuous fixation. Joint fixation periods were for 2 and 4-weeks. Ankle joint range of motion and soleus flexibility were analyzed. [Results] For the 2-week joint fixation, soleus flexibility in Group 4 showed an increase compared with that of Group 3. For both fixation periods, range of motion in Group 4 showed an increase compared with that of Group 3. [Conclusion] For both fixation periods, stretching improved joint range of motion. In the 2-week joint fixation, soleus flexibility improved. However, soleus flexibility did not improve in the 4-week joint fixation.

Key words: Muscular contracture, Stretching, Muscular flexibility

INTRODUCTION

Contractures result in a decrease of joint range of motion (ROM) and are caused by the skin, muscle, tendon, and joint capsule that exist around the joint. In particular, contractures caused by a muscle are called muscular contractures. Muscle participation in ROM decrease changes with prolongation of the joint fixation period1). Therefore, when assessing contractures, the fixation period must be considered. Fixation is put into effect in orthopedic treatments using a cast. Clinically, stretching is performed to improve muscle flexibility. However, stretching torque has not been clearly determined. In previous studies2), 3), the influence of stretching contractures has been examined using animals, but the number of times that stretching was performed has not been consistent. To adequately evaluate the influence of stretching, it is necessary to standardize the number of times it is performed.

The purpose of this study was to investigate how stretching torque based on weight affects muscular contractures.
the sole of the foot by a tension meter (LTS-1KA; Kyowa Electronic Instruments Co., Ltd., Japan)\(^5\). Then, a digital photograph was taken from directly above the hind limb, and the angle of dorsiflexion was measured with computer software (Image J 1.44p, U.S. National Institutes of Health, Bethesda, MD, USA). To eliminate forefoot movement from the measurement, the dorsiflexion ROM was defined as the angle obtained from a line parallel to the longitudinal axis of the fibula and a line parallel to the bottom of the heel. During ROM measurements, the knee joint was flexed.

To measure the degree of soleus flexibility, the length-tension curve of the soleus was determined using an Autograph (AG-50KNG; Shimadzu Corp., Japan)\(^6\). Under anesthesia (sodium pentobarbital, 40 mg/kg), the ankle was positioned in full plantar flexion, and the calcaneus and tibia were fixed with a 0.7 mm Kirschner wire. Then, the skin and gastrocnemius were removed surgically. After sacrificing the rat, the femur was cut above the origin of the gastrocnemius and mounted on the Autograph with the upper clamp. The tarsal bone was mounted with the lower clamp. The tibia, fibula, and all lower leg muscles, except for the soleus, were cut, and the tension torque was measured at the 10 mm lengthened position of the soleus muscles\(^8\).

Data are expressed as mean ± standard deviation. The Kruskal-Wallis test was used for analysis of ankle joint dorsiflexion ROM and soleus flexibility. The Steel-Dwass test was used for the post-hoc comparison. Statistical analyses were performed using Excel Statistics 2010 (Social Survey Research Information Co., Ltd., Tokyo, Japan). Significance was accepted for values of p < 0.05.

### RESULTS

Dorsiflexion ROM data are shown in Table 1. In both the 2-week and 4-week joint fixation periods, significant differences were observed among the 4 groups. Compared with Group 2, ROM in Groups 3 and 4 showed an increase; compared with Group 3, ROM in Group 4 showed an increase. Soleus flexibility data are shown in Table 2. In the 2-week joint fixation period, significant differences were observed among the 4 groups. Compared with Group 3, soleus flexibility in Group 4 showed an increase. In the 4-week joint fixation period, compared with Group 2, soleus flexibility in Groups 3 and 4 did not show an increase.

### DISCUSSION

Generally, stretching improves muscle flexibility\(^9\). In muscular contractures, joint fixation for more than 4 weeks changes the arrangement of the endomysium\(^9\), and the amount of collagen increases in the muscle\(^10, 11\). In our study, soleus flexibility improved with a 3.0 N torque in the 2-week fixation, but did not improve with a 3.0 N torque in the 4-week fixation. In the 4-week fixation, the soleus showed morphological and physiological features as reported in a previous study. In the 2-week fixation, such morphological and physiological features did not occur. Therefore, soleus flexibility in the short joint fixation period improved with stretching. However, in the long joint fixation period, one 30-minute stretch was insufficient to improve the morphological and physiological features found in the soleus. In normal joints, ROM is increased by a stretching torque\(^12\). In our study, dorsiflexion ROM was increased by a stretching torque; however, the 0.3 N stretching torque did not increase soleus flexibility. ROM is dependent on flexibility of the skin, muscle, tendon, and joint capsule\(^13\). In our study, we concluded that stretching had an influence on skin and joint capsule flexibility. We suggest that a 0.3 N stretching torque improves skin flexibility and/or joint capsule flexibility.

A limitation of this research was lack of consideration for convalescence after stretching. Therefore, research is needed regarding how muscle flexibility is influenced by muscular convalescence after stretching.

### REFERENCES

1) Trudel G, Ulthoff HK: Contractures secondary to immobility: is the restriction articular or muscular? An experimental longitudinal study in the rat knee. Arch Phys Med Rehabil, 2000, 81: 6–13. [Medline] [CrossRef]
2) Takemura K, Hosoi M, Tachino K, et al.: Histopathological effects of the stretching on joint components after two-week knee joint immobilization in rats. Rigakuryohogaku, 2004, 31: 76–85 (in Japanese).
3) Inoue T, Okita M, Takahashi Y, et al.: Effect of intermittent stretching on limitation of ankle joint mobility and diuse muscle atrophy in immobilized rat soleus muscle. Rigakuryohogaku, 2007, 34: 1–9 (in Japanese).
4) Williams PE: Use of intermittent stretch in the prevention of serial sarcomere loss in immobilised muscle. Ann Rheum Dis, 1990, 49: 316–317. [Medline] [CrossRef]
5) Ono T, Oki S, Miyoshi M, et al.: The effect of ROM exercise on rats with denervation and joint contracture. J Phys Ther Sci, 2009, 21: 173–176. [CrossRef]

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**Table 1. ROM of ankle joint dorsiflexion (in degrees)**

| Group   | 2-week joint fixation | 4-week joint fixation |
|---------|-----------------------|-----------------------|
|         | Group 1 | Group 2 | Group 3 | Group 4 | Group 1 | Group 2 | Group 3 | Group 4 |
| 2-week  | 137.5±1.2 | 76.5±3.7 | 85.5±3.0 | 110.0±5.7 | 136.5±1.6 | 66.4±3.5 | 74.0±4.9 | 89.1±5.2 |
| fixation|         |         |         |         |         |         |         |         |

Data are presented as mean ± SD
*: significant increase compared with Group 1
†: significant increase compared with Group 2
‡: significant increase compared with Group 3

**Table 2. Soleus flexibility (in newtons)**

| Group   | 2-week joint fixation | 4-week joint fixation |
|---------|-----------------------|-----------------------|
|         | Group 1 | Group 2 | Group 3 | Group 4 | Group 1 | Group 2 | Group 3 | Group 4 |
| 2-week  | 0.19±0.09 | 1.73±0.40 | 1.89±0.31 | 0.81±0.20 | 0.20±0.06 | 2.18±0.47 | 2.22±0.39 | 1.80±0.85 |
| fixation|         |         |         |         |         |         |         |         |

Data are presented as mean ± SD
*: significant increase compared with Group 1
†: significant decrease compared with Group 2
‡: significant decrease compared with Group 3
6) Ono T, Oki S, Shimizu ME, et al.: The influence of spinal cord injury and peripheral nerve injury on muscle elasticity in contractures of the soleus muscle of rats. J Phys Ther Sci, 2006, 18: 1–3. [CrossRef]
7) Oki S, Sibata T, Matsuda Y, et al.: The appearance and the progression of muscle contracture in the immobilized muscle. J Phys Med, 1998, 9: 38–41.
8) Palmer ML, Claflin DR, Faulkner JA, et al.: Non-uniform distribution of strain during stretch of relaxed skeletal muscle fibers from rat soleus muscle. J Muscle Res Cell Motil, 2011, 32: 39–48. [Medline] [CrossRef]
9) Okita M, Yoshimura T, Nakano J, et al.: Effects of reduced joint mobility on sarcomere length, collagen fibril arrangement in the endomysium, and hyaluronan in rat soleus muscle. J Muscle Res Cell Motil, 2004, 25: 159–166. [Medline] [CrossRef]
10) Sugama S, Tachino K, Haida N: The effect of immobilization on tendon collagen solubilities: biochemical studies on collagen from rat achilles tendon. Rigakuryohogaku, 1995, 22: 196–201 (in Japanese).
11) Sugama S, Tachino K, Haida N: The effect of immobilization on muscle and tendon collagen solubilities: biochemical studies on collagen from rat muscle and tendon tissues. Rigakuryohogaku, 1996, 23: 72–79 (in Japanese).
12) Bohannon RW, Tiberio D, Zito M: Effect of five minute stretch on ankle dorsiflexion range of motion. J Phys Ther Sci, 1994, 6: 1–8.
13) Okamoto M, Okita M, Kasuya A, et al.: Effects of immobilization period on restriction of soft tissue and articulation in rat ankle joint. Rigakuryohogaku, 2004, 31: 36–42 (in Japanese).