Comparison of foot pressure in stretching exercises according to the type of ankle ramp

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Abstract. [Purpose] This study compared and analyzed use of an existing ankle ramp and a newly developed ankle ramp for stretching exercises. [Subjects] Fourteen subjects were included; they were stroke patients more than 6 months after onset, with no orthopedic or biological problems in the legs, so independent gait was possible. [Methods] The subjects performed stretching exercises for 5 min with an existing ankle ramp and a newly developed ankle ramp; foot pressure was then measured. [Results] The averaged percentage and kilopascal data for weight bearing and foot pressure on the affected side with the newly developed ankle ramp for stretching exercises were significantly higher than those with the existing ankle ramp. [Conclusion] Our results suggest that stretching exercises using the newly developed ankle ramp more effectively increase foot pressure than the existing ankle ramp.

Key words: Ankle ramp, Foot pressure, Stroke

INTRODUCTION

Neurological injury, such as in stroke, may lead to contracture and spasticity that can be severely disabling1). Impairment of ankle joint motion, such as reduced ROM and tight calf muscles, can result in abnormal gait patterns with excessive energy costs2). In particular, lack of exercise capacity in the legs affects walking ability and balance and increases the risk of falls3). Musculoskeletal changes, such as abnormal joint stiffness and limited ROM, may lead to restrictions in a patient’s functional movements as well as movement of the joint4). Previous methods for increasing joint flexibility include cold treatment, heat treatment, massage, electrical therapy, active exercise, static stretching techniques, and hold-relax techniques5). Several clinical studies have made use of the stretching force produced using a solid splint or using the patient’s body weight when standing in an upright position5). Passive ankle stretching has been used in both clinical treatment and in sports training, and its effects on joint characteristics, such as the stretch reflex, maximum voluntary contraction, joint stiffness, and gait, have been documented6). Foot drop after a stroke produces ankle plantar flexion, inversion, and the need for an ankle ramp for stretching exercises. The existing ankle ramp is helpful only for dorsiflexion and ineffective for eversion. Thus, the purpose of this study was to compare the use of existing and newly developed ankle ramps for stretching exercises.

SUBJECTS AND METHODS

Fourteen subjects (11 males, 3 females) were recruited. The subjects were stroke patients more than 6 months after onset who had no orthopedic or other biological problems of the legs, so independent gait was possible. Subjects were excluded if they had amblyopia, vertigo, or vestibular dysfunction. Their average age, height, and weight were 59.8±5.8 years, 171.6±7.8 cm, and 71.7±6.2 kg, respectively. Ethical approval was obtained from the Inje University Faculty of Health Science Human Ethics Committee. Subjects provided written informed consent to participate prior to the commencement of the study. The existing ramp induces only dorsiflexion, but the newly developed ankle ramp can help not only with dorsiflexion but also with ankle eversion. Structurally, the device is made of plywood and has a hinge that can be used to adjust the angle to 10, 20, or 30°. The gait posture assessment (GPA) system consisted of software for podoscopy and a Gaitview system. Podoscopy was used to measure ankle alignment and the extent of plantar departure, and the Gaitview system was used to measure aspects of foot pressure through weight distribution. This study evaluated foot pressure by means of the weight distribution, and the value was converted to a percentage. The subjects were provided with an explanation of the experimental procedures and practiced twice with the ankle ramp and measuring equipment. They underwent three
foot pressure measurements before and after application of the ankle ramp. The averages of these values were recorded. The subjects maintained static stretching for 5 min using the ankle ramp, and then aspects of foot pressure were measured immediately using the GPA system. The ramp used was selected randomly, and subjects took a break for 2 h to minimize any impact of fatigue before using the other ankle ramp. The data were analyzed using one-way repeated-measures analysis of variance (ANOVA). A Bonferroni correction was performed to identify specific differences between multiple pair-wise comparisons. All significance levels were \( p < 0.05 \). The SPSS software (ver. 20.0; IBM, Armonk, NY, USA) was used for the statistical analyses.

RESULTS

After using the newly developed ankle ramp in stretching exercises, the averaged percentage and kilopascal data of weight bearing and foot pressure on the affected side were 55.4\(\pm\)4.4\% and 51.2\(\pm\)9.5 kPa, respectively. The averaged percentage and kPa data with the newly developed ramp were significantly higher than those with the existing ankle ramp, 52.2\(\pm\)3.1\% and 47.6\(\pm\)6.3 kPa, respectively (\( p < 0.05 \)). The data were analyzed using one-way repeated-measures analysis of variance (ANOVA). A Bonferroni correction was performed to identify specific differences between multiple pair-wise comparisons. All significance levels were \( p < 0.05 \). The SPSS software (ver. 20.0; IBM, Armonk, NY, USA) was used for the statistical analyses.

DISCUSSION

In this study, weight bearing and foot pressure on the affected side were significantly higher with the newly developed ankle ramp for stretching exercises than with the existing ankle ramp. When muscles are immobilized in a shortened condition, they exhibit reduced muscle length, reduced extensibility, and enhanced passive viscoelastic stiffness. With regard to the ankle in particular, “foot drop” occurs, and the ankle becomes deformed with reduced plantar flexion, inversion, and contracture over time. To treat this, stretching exercises are commonly used clinically, and previous studies have reported that stretching with a lasting angle affects the viscosity of the muscle tendon. Previous research also suggests that the change in mechanical conditions of the tendon depended on the type of stretching. In addition to changes in joint mechanical conditions, repeated ankle stretching can alter conditions at the muscle fascicle level. It has been reported that the stretching of muscles can be a stimulus for a normal postnatal increase in sarcomere units. Thus, stretching exercises are frequently used in the clinic. Among them, static stretching with an ankle ramp is often used. However, existing ramps focus only on stretching for dorsiflexion, without eversion. This appears to address only half of the problem in ankle contracture therapy for foot drop. Thus, the ramp newly developed for this study was designed to address these disadvantages and improve weight bearing and foot pressure on the affected side compared with existing ramps, as demonstrated by the results of this study. Therefore, an ankle ramp with a slope in the center for efficient ankle stretching will help not only dorsiflexion but also eversion. Finally, our results suggest that stretching exercises using the newly developed ankle ramp can more effectively increase foot pressure than those using the existing ramp because the new ramp yields results balanced for the patient’s weight on both sides.

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