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不同牽張治療模式對下肢痙攣之量化分析
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不同牽張治療模式對下肢痙攣之量化分析

Comparing Three Modalities of Sustained Muscle Stretching Treatments for Suppression of Ankle Hypertonia in Hemiplegic Patients

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中文摘要

肌肉張力異常是上運動神經元疾病患者臨床上常見的症狀。臨床上使用持續肌肉牽張的治療方法，對於小腿後肌已證明具有降低肌張力的療效。然而肌肉牽張的治療方式，卻因痙攣程度量化不易及牽張強度無定量描述而無法有標準的治療規範。之前我們發展出一套能隨時偵測長時間伸張治療的力量，且兼具伸張治療及評估的儀器； 經過驗證後顯示，在評估及治療方均可達到設計的速度與角度。

因此，本研究的目的是要比較固定角度、固定力量與正弦牽張三種治療模式對痙攣組織在臨床評估、神經生理及生物力學評估上之治療效果是否有差異。研究結果顯示，固定力量的牽張治療模式不論在臨床評估、神經生理及生物力學評估上之治療效果均較其他兩種治療模式有顯著的差異，此結果可提供臨床人員在降低肌肉張力上另一更有效之治療方式。

關鍵詞：痙攣、中風、牽張、復健

Abstract

Present study compares the effectiveness of three different sustained muscle stretch (SMS) modalities in the suppression of ankle hypertonia. Forty-seven hemiplegic subjects with hypertonic ankle joint were recruited for three SMS modalities of treatments. The hypertonic ankle joints were stretched using an integrated treatment/assessment system capable of conducting three modalities of SMS treatments. The immediate post-treatment effectiveness of each stretching modality was assessed by reference to the Modified Ashworth Scale (MAS), by measuring the passive range of motion (ROM), and by means of a reactive torque measurement, from which the viscous-elastic component of the ankle joint can be derived. The three SMS modalities yield an increase in the ROM value. Additionally, each stretching method successfully reduces the MAS grade and the elastic and viscous components of the ankle joint ($p<0.05$). The changes in the ROM, elasticity, and viscosity are most pronounced in the case of the constant-torque stretching modality.

Keywords: Rehabilitation, spasticity, hypertonia, sustained muscle stretch

INTRODUCTION

Despite some functional gains in maintaining muscle mass and improving posture, muscle spasticity with excessive muscle tone is considered as one of the principal factors affecting the rehabilitation of patients suffering from upper motor neuron lesions.[1] The biomechanical properties of muscle, commonly expressed as joint stiffness, refer to the increased resistance encountered during passive movement of the limb, which are known to increase in long-standing spasticity.[2] There are many sources of the joint stiffness during passive movement: the joint capsule, ligament and musculo-tendinous unit, etc.[3] Several researchers have described joint stiffness as a whole in terms of its elastic and viscous components based on a second-order biomechanical model [2].

Various forms of physical therapy interventions are commonly employed to alter the biomechanical properties of the spastic muscle with the aim of reducing symptoms related to spasticity following stroke.[4] Of these techniques, sustained muscle stretch (SMS), also called prolonged muscle stretch, is commonly used to stretch the spastic muscles.[3] In conventional SMS treatment specifies a fixed stretching angle, and is therefore referred to as constant-angle SMS. An alternative approach to constant-angle SMS is the so-called cyclic SMS modality. This method alleviates the discomfort experienced by the patient during the constant-angle SMS session.[6] The constant-angle and cyclic SMS modalities both mainly focused upon the appropriate specification of the stretching angle.[5-8] It is noticeable that previous studies generally did not consider the stretching force aspects of SMS treatment.

the current authors have developed a novel approach referred to as constant-torque SMS, which utilizes a computer-controlled stretching device to maintain a constant stretching force over the duration of the treatment session.[9,10] Constant-torque SMS exploits an important characteristic of the musculo-tendinous unit of the spastic ankle joint, namely the creep phenomenon in which the stretching force is maintained at a constant value, but the stretching angle is continuously increased.

The purpose of the present study is to compare the effectiveness of the constant-angle, cyclic, and constant-torque SMS modalities in suppressing ankle hypertonia. The relative effectiveness of each technique is evaluated by reference to the MAS clinical scale, measurement of the ROM, and biomechanical assessments of the elastic and viscous components of the passive ankle joint stiffness.

METHODS

Forty-seven subjects (30 men and 17 women) aged 40 to 75 years old (mean ± SD, 53.7±10.3 yr) were recruited for the present study. Each of the subjects had suffered from spastic hemiplegia arising from cerebrovascular accidents (CVA) for between 4 months and 5 years (22.4±16.0 m). Subjects with CVA were considered to be eligible to take part in the study if they had hypertonia in a lower limb, no joint deformity on the affected limb, no pain in the lower limb, and no previous history of neurological disorder. All subjects signed an informed consent approved by the Medical Ethical Committee of the Chung-Shan Medical University.

Each subject underwent three treatment sessions, with each session separated by a period of one week. Prior to SMS treatment, the stiffness of the ankle joint was evaluated by a senior therapist in accordance with the clinical Modified Ashworth Scale (MAS). An average of three measurements of the passive ROM of the ankle dorsiflexion was then recorded using a goniometer. An integrated hypertonia treatment/assessment system, as shown in Figure 1, was used to assess the viscoelastic properties of the plantarflexors using sinusoidal stretching techniques, which are a common means of conducting biomechanical assessments of joint stiffness.[2]

Over the three-week test period, each subject underwent constant-angle, cyclic, and constant-torque stretching treatments of the ankle joint. The sequence in which the different SMS modalities were conducted for each patient was specified randomly. As mentioned above, the three treatment sessions were spaced at an interval of one week and were each conducted at the same time of day. As in previous SMS studies[4,6,8], the duration of each session was specified to be 30 minutes. Following each stretching session, the MAS grade and the maximal dorsiflexion angle were re-measured, and the biomechanical assessment of joint stiffness repeated.

The MAS, passive ROM, and reactive torque value recorded at a stretching velocity of 5˚/sec were recorded before and immediately following each treatment session. Regarding the biomechanical assessment using sinusoidal stretches, three stretching trials were performed at each of ten stretch frequencies (3-12 Hz) for each subject and the results were then averaged across the 47 subjects. In our previous study, a quantitative technique has been developed to obtain the elastic-inertia component (Kei) and the viscous component (Kv).[9] The degree of spasticity of the joint is then quantified on the basis of the elastic (Kei) and the viscous (Kv) components derived from the measured reactive torque value. The paired t test was used to analyze the differences between the pre- and post-treatment values of the ROM, Kei and Kv values. The Wilcoxon signed rank test was employed to analyze the differences in the pre- and post-treatment MAS values. To compare treatment effects of three SMS modalities, the repeated measures of the MANCOVA method were used to determine whether a statistically significant difference existed in the reduction of the ROM, Kei and Kv values of the ankle joint within the three SMS modalities. The co-variables were taken as the values recorded during the pre-treatment assessments. Post hoc analyses were again performed using the Bonferroni test. The Kruskal-Wallis one-way analysis of variance was used to compare the differences between the MAS values for each stretching modality. It is noted that a significance level of 0.05 was applied throughout the tests in the current study.

RESULTS

The stretching force gradually decreases over the duration of the treatment session for the constant-angle and cyclic SMS modalities, i.e. the force decreases by 46.57±4.79% and 36.82±2.25% of its initial value, respectively. However, for the constant-torque SMS modality, the force remains constant (100.70±0.72%) as a result of drive motor adjustments instructed by the computer-programmed stretching motor in accordance with the monitored torque. The results indicated that the stretching angle of the ankle dorsiflexion is precisely maintained at a constant value of 101.00±0.01% and 100.57±0.40% of the preset value for the constant-angle and cyclic SMS modalities, respectively. In contrast, the stretching angle increases continuously to a final value of 168.55±20.85% of the original stretching angle over the course of the constant-torque SMS treatment session.

Comparing pre- and post- treatment effects of three SMS modalities

Prior to SMS treatment, the MAS, ROM, and torque of the affected ankles of the hemiparetic subjects were measured. Our results indicate a significant reduction in the MAS grades following a single SMS treatment session regardless of the particular modality employed ($p<0.05$). It is observed that the average ROM of the ankle dorsiflexion increases significantly after a single SMS treatment session for each of the three modalities, i.e. from 9.72˚ to 16˚, 9.56˚ to 14.81˚, and 9.19˚ to 18.28˚ for the constant-angle, cyclic, and constant-torque modalities, respectively ($p< 0.05$, Table 1).

Regarding the biomechanical assessments, the effectiveness of each SMS modality was investigated by comparing the averaged means and standard deviations of the Kei and Kv values before and after a single treatment session. The Kei and Kv values are significantly lower following the constant-angle SMS treatment ($p<0.05$), similar results are also observed for the cyclic and constant-torque modalities. The current results indicate that each SMS treatment modality yields a significant reduction ($p<0.05$) in the Kei and Kv values following a single treatment session.

Comparison of treatment effects of three treatment modalities

A further comparison of the increments in the ROM values between constant-angle and cyclic-stretching treatments reveals no significant differences ($p>0.05$). However, the increment in ROM obtained from the constant-torque treatment is significantly higher than the improvements obtained from the constant-angle and cyclic SMS modalities ($p<0.05$).

It reveals that there is no significant difference between the changes in Kei and Kv for the constant-angle and cyclic SMS modalities ($p>0.05$). However, Figure 2 indicates that the changes in Kei and Kv for the constant-torque modality are significantly different from those recorded for the constant-angle and cyclic stretching treatments ($p< 0.05$)

DISCUSSION

Current study utilized ROM, MAS and biomechanical measurements to evaluate the treatment effects of the constant-angle, cyclic and constant-torque SMS modalities. In general, a significant increase in the ROM value together with significant decreases in the MAS grades and biomechanical parameters (Kei and Kv) indicate a positive spasticity treatment effect. A comparison of the pre- and post-treatment results for the three treatment methods confirms the effectiveness of each modality in suppressing hypertonia.

During clinical grading the MAS, the ankle is commonly moved by clinical personnel to excite abnormal reflex activity whereas the manually stretching movement is generally not consistent for each trial. Previous studies indicated that the MAS cannot precisely identify the cause of resistance. In present study the biomechanical measurement is used to investigate the influences of stretching on the viscoelastic properties of the musculo-tendinous unit. Our results indicate that the viscous and elastic components of the ankle joint stiffness are both suppressed following three types of SMS treatments.

Research studies into stretch maneuvers for the human muscle-tendon unit in vivo emphasize both the parallel and the series elastic components. Other in-vivo studies indicated the series elastic components of the muscle are associated with muscle elasticity, while the parallel elastic components are related to muscle viscosity. Our study implies that the properties of series and parallel elastic components may have been changed after being stretched, resulting in smaller Kei and Kv parameters. However, the underlying physiological mechanisms resulting in hypertonia suppression following SMS require further investigations.

Our results indicate that there is no significant difference between the changes in ROM, MAS, Kei and Kv values obtained from constant-angle SMS and those obtained from cyclic SMS. This result is consistent with the findings of a previous study,[5] which concluded that neither technique holds the advantage in reducing stiffness in stroke patients. However, most subjects expressed the view that the cyclic stretching method was more comfortable.[7] The changes in the ROM, Kei and Kv values obtained from the constant-torque modality are significantly larger than those obtained from constant-angle and cyclic stretching. In terms of immediate post-treatment effectiveness, constant-torque stretching seems to be more effective than either the constant-angle or cyclic stretching modalities. Taking both comfort and treatment effectiveness into consideration, our on-going project is to modify the integrated treatment/assessment device such that it is capable of performing cyclic stretching with constant-torque.

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Table 1. Mean and standard deviation of ROM and range of MAS in pre- and post- treatment assessments for constant-angle, cyclic-stretching and constant-torque treatments.

	constant-angle	cyclic-stretching	constant-torque
ROM [a]			
pre	9.72±6.22	9.56±5.54	9.19±5.18
post	16.00±7.54	14.81±5.99	18.29±5.09 [c]
MAS [b]			
pre	1-3	1-3	2-3
post	1-3	0-3	0-1

[a] and [b] variables showed significant difference between pre and post test $p<0.05$ [c]variables showed significant difference between constant-torque and two other SMS treatments, $p<0.05$.

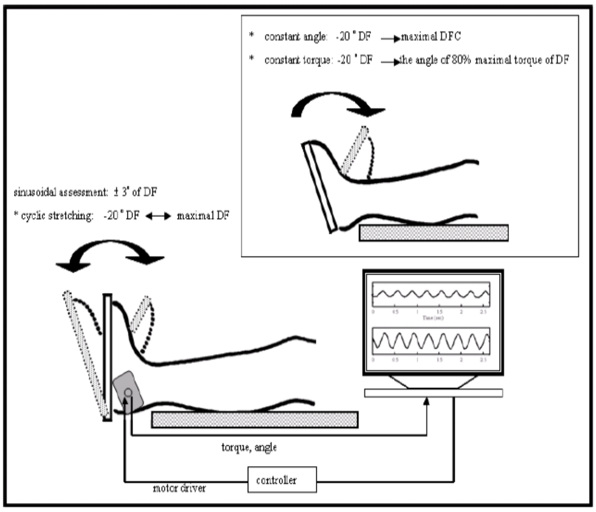

Figure 1 Experimental setup for three modalities of SMS treatments

Figure 4. Changes in Kei and Kv values after 30-minute constant-angle, cyclic and constant- force stretching treatment sessions.