Relaxing Effect of Acupuncture Stimulation on Hypertonic Muscle in a Rat Model

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Abstract

Background: The relaxing phenomenon induced by acupuncture on hypertonic muscle has not clearly been demonstrated. We studied whether acupuncture stimulation on the hypertonic muscle model induce relaxation.

Methods: A rat model of hypertonia was created by inducing tetanic contraction in the triceps surae muscles of 21 Wistar rats (male, 12 weeks) with four electrical stimulations (80 Hz, 5 mA, 5 min.), with a 2 min. interval between each stimulation. The rats were randomly divided into two test groups: 1. Untreated group (N = 12), 2. Group treated with acupuncture stimulation of the triceps surae muscle (N = 9). Rats in the untreated group received no therapeutic treatment after the model was created. Acupuncture was performed within 5 min. after the model was created. Evaluations were taken before and 5 min., 1, 2 and 3 days after tetanic contraction was induced. The rats were anaesthetized and a tension sensor for measuring static and dynamic muscle tension was used to determine triceps surae muscle stretching tension during passive dorsal flexion of the foot (30°, 40°, 50°).

Results: In both groups, at each of the angles of passive dorsal flexion, there was a significant increase in stretching tension 5 min. after inducing tetanic contraction compared to before induction, and statistics showed recovery to pre-induced tetanic contraction values after 1 day and thereafter. Compared to the untreated group, however, values 5 min. after induced tetanic contraction tended to be lower in the group treated with acupuncture stimulation.

Conclusions: Compared to the untreated group, stretching tension values 5 min. after inducing tetanic contraction tended to be lower in the acupuncture group. This could be due to acupuncture stimulation causing changes in blood flow in the lower leg, including muscle tissue, resulting in reuptake of calcium by the sarcoplasmic reticulum, and/or the influence acupuncture on reducing lower leg edema. Acupuncture stimulation could also have an action on the γ fibers and Ib fibers associated with continuous muscle tonus and muscle relaxation.

Keywords: Rat, Muscle, Hypertonic, Acupuncture, Relaxation

I INTRODUCTION

It has been previously said that the major beneficial effects acupuncture stimulation has on
the human body are activation of the pain control systems in the upper central nervous system, spinal cord, and peripheral tissue\(^{1-5}\), and its action on the autonomic nervous system leading to changes in haemodynamics\(^{6,7}\), which together combine to provide a relaxing effect on muscle tonus.

Although there have been said that the relaxing effect acupuncture treatment has on excessive muscle tonus, they have focused only on changes in tightness determined by applying pressure to the surface of the skin before and after acupuncture stimulation, and subjective clinical changes. There has been hardly any objective research of this phenomenon and the actions involved are still unclear\(^{8}\). Furthermore, from the clinical point of view, rather than changing the degree of muscle tightness when pressed from the skin, relaxing excessively tense muscle means having the effect of increasing the range of motion of joints associated with the muscle and improving mobility.

With the aim of clarifying whether acupuncture treatment has a relaxing effect or not on hypertonic muscle, an experimental animal model with hypertonic triceps surae muscle was created. Taking the force applied to the axis of rotation (triceps surae muscle stretching tension) during passive dorsal flexion of the foot to a set angle as an index, the difference between stretching tension in untreated animals and animals treated with acupuncture stimulation was examined.

II METHODS

A rat model of hypertonia was created in the right triceps surae muscles of 21 male Wistar rats (12 weeks, 280–310 g). Using a stimulator (SEN-3301, Nihon Kohden Corporation, Tokyo, Japan) and isolator (SS-104J, Nihon Kohden Corporation, Tokyo, Japan), tetanic contraction of the right triceps surae muscle was induced with a total of 4 electrical stimulations (stimulation frequency: 80 Hz, 1 ms square pulses, stimulation strength: 5 mA, stimulation time: 5 min) performed at intervals of 2 min using 2 needle electrodes (0.22 mm in diameter, Nihon Kohden Corporation, Tokyo, Japan) subcutaneously inserted 1 cm into the back of the right lower leg of anaesthetized rats (pentobarbital, 50 mg/kg, i.p.). The hypertonia model rats were randomly divided into an acupuncture stimulation group (N = 9) and untreated group (N = 12) that received no acupuncture stimulation. Acupuncture stimulation was performed for 5 min directly after creation of the tetanic contraction model at 5 sites in the triceps surae muscle (1 each at the medial head and lateral head of the gastrocnemius muscle, 3 at the junction for muscle tendon in the triceps surae muscle). Needles at each site were inserted to a depth of 1 cm, and 5 mm amplitude “sparrow pecking” (after insertion of a needle to the desired depth, manual changing of needle depth at a fixed rhythm of 1 Hz) was performed for 1 min. In the untreated group, no acupuncture treatment was performed after creation of the model. Muscle tension was assessed with a static and dynamic muscle tension measuring device (for measuring torque in rats) (VINE, Japan). The rats were anaesthetized (pentobarbital, 50 mg/kg, i.p.), placed on a measurement table in a stable, supine position with the lower right limb flexed at an angle
of 45° at the hip and knee. The plantar surface was then fixed to a rotation table equipped with a tension sensor at an angle of 0°. Under these conditions, dorsiflexed the ankle joint upward to 30°, 40° and 50° passively and measured the force placed on the axis of rotation of the table, in other words measured them as the degree of triceps surae muscle stretching tension. Measurements were taken before and 5 min (directly after acupuncture in the acupuncture group), 1, 2 and 3 days after tetanic contraction was induced.

III  STATISTICAL ANALYSIS

All data were expressed as mean ± standard deviation. Intra-group values at each measurement angle before creation of the tetanic model and at each time of measurement were compared using one-way analysis of variance and the Bonferroni-Dunn multiple comparison test. Inter-group comparisons of values at each measurement angle and at each time of measurement were conducted using two unpaired t-tests followed by Bonferroni’s adjustment. Results were considered significant when the p value was less than 0.05.

IV  RESULTS

In both the untreated and acupuncture groups, 5 min after inducing tetanic contraction, the stretching tension at each dorsal flexion angle of the foot was significantly higher than before inducing tetanic contraction. No significant different was observed between the groups. In the acupuncture group, however, the values tended to be lower than those in the untreated group (Figures 1-3). Furthermore, at day 1 after inducing tetanic contraction, values in the untreated group recovered to pre-induced tetanic contraction values at each of the dorsal flexion angles, while values in the acupuncture group tended not to return to pre-induced tetanic contraction values although no statistical significance between the values. At day 2 after inducing tetanic contraction, stretching tension values of untreated group at each of the dorsal flexion angles tended to increase again to the same range of value of the acupuncture group, which had still not completely recovered (Figures 1-3). At day 3 after inducing tetanic contraction, values in both the untreated and acupuncture groups had almost completely recovered to pre-induced tetanic contraction (Figures 1-3).

V  DISCUSSION

In general, the main effects of acupuncture treatment are said to be pain inhibition, an influence on tissue circulation, and alleviation of muscle tightness. There are a comparatively large number of reports concerning the effects of acupuncture stimulation on the activation of the pain inhibition mechanism in the descending pain modulatory system, spinal segmental analgesia system and diffuse noxious inhibitory control\(^1\),\(^3\)-\(^5\). Several studies have also been conducted on the effects of acupuncture stimulation on tissue circulation. It is known that through its action on the autonomic and somatic nervous systems, acupuncture influences arterioles and changes capillary bed blood flow\(^6\). There have not, however, been any studies to
Fig. 1  Triceps surae muscle stretching tension during passive 30° dorsal flexion of the foot
All values presented were mean ± SD
* p < 0.05 vs Before inducing tetanic contraction

Fig. 2  Triceps surae muscle stretching tension during passive 40° dorsal flexion of the foot
All values presented were mean ± SD
* p < 0.05 vs Before inducing tetanic contraction
clarify the mechanisms behind the relaxing effect of acupuncture stimulation on hypertonic muscle or even the phenomenon itself because until now the knowledge has been based solely on the subjective experiences of practitioners. Among a few related studies, changes in muscle hardness determined by applying pressure to the skin’s surface after acupuncture stimulation have been reported\(^8\). It is thought that these changes cannot be directly linked to changes in muscle tightness alone and that the main disadvantage for patients with hypertonic muscle is the negative effects to the mobility and flexibility of connected joints resulting in reduced motor function. Using dorsal flexion mobility of the foot, which is connected to the triceps surae muscle, as an index, this study examined whether acupuncture stimulation influences transient hypertonia in rat triceps surae muscle induced with repeated tetanic contractions.

For this study, a hypertonic model created by repeatedly inducing tetanic contractions. In both the untreated and acupuncture groups triceps surae muscle stretching tension continued to keep increasing for at least 5 min after tetanic contractions were induced, and at day 1 at the latest, values had statistically recovered to pre-induced tetanic contraction values. Consequently, although it was not a long-term hypertonia model, it was considered possible to use it as a transient hypertonia model.

A comparison of the untreated and acupuncture groups of rat models showed no significant difference 5 min after creation of the model but after acupuncture stimulation, triceps surae muscle stretching tension tended to be lower. As a result, it was thought that acupuncture stimulation of the triceps surae muscle could have had an inhibitory action on the hypertonia.

Fig. 3  Triceps surae muscle stretching tension during passive 50° dorsal flexion of the foot
All values presented were mean ± SD
* p < 0.05 vs Before inducing tetanic contraction
This study did not clarify the mechanism involved in this phenomenon and the details are still unclear. Since it has been reported that acupuncture stimulation of muscle causes changes in muscle haemodynamics\(^7\),\(^10\), it is possible that changes in muscle blood flow due to acupuncture stimulation influence the reuptake of calcium by the sarcoplasmic reticulum which is related to muscle contraction and relaxation. Furthermore, the electrical stimulation used to create the model at the time of inducing tetanic contractions or later, could have caused edema in the entire lower leg due to increased blood flow in the capillary beds of skin, subcutaneous tissue and muscle. In this study, needles were inserted into muscle percutaneously, so as well as the muscle, the skin and subcutaneous tissue were simultaneously stimulated. Since acupuncture stimulation has an influence on blood flow to the skin and subcutaneous tissue as well as the muscle, acupuncture stimulation could have had the effect of reducing edema in the entire lower leg\(^11\), whereat reducing resistance during passive stretching of the triceps surae muscle. Acupuncture stimulation could also have directly or indirectly influenced neurological factors related to continuous muscle tonus or muscle relaxation such as Ib fibers related to tendon organs and \(\gamma\) fibers corresponding to muscle spindles, or else \(\alpha\) motor neurons directly related to muscle contraction. In addition, the induced tetanic contractions when creating the model may have caused pain. It has been reported that the occurrence of pain influences \(\gamma\) fibers via muscle sympathetic nerves which may cause muscle tonus\(^12\). Consequently, consideration must be given to the possibility that acupuncture stimulation has an inhibitory action on pain due to hypertonic conditions resulting in reduced muscle sympathetic nerve activity and a relaxing effect on hypertonic muscle.

Since it has been pointed out that acupuncture stimulation could have the effect of activating the descending inhibition system resulting in an inhibitory action on \(\gamma\) motor neurons in the spinal cord, it is thought that the inhibition of \(\gamma\) motor neuron activity may be involved in muscle relaxation\(^13\).

Observation of the course after inducing tetanic contractions verified that even at day 1 after inducing the contractions, in the acupuncture group triceps surae muscle stretching tension values had not returned to pre-induction values, and the values tended to be higher than those in the untreated group. The reason for this was thought to be that inflammation in the subcutaneous tissue of the lower limb including muscle tissue due to acupuncture, which is recognized as being a noxious stimulation, could have caused edema in the lower limb that had an effect on resistance during passive dorsal flexion of the foot. Since the needles used for humans were used to smaller muscles of rats compared to human, it is highly possible that the rats were over-stimulated. Future study results are needed with different diameters needles inserted to different depths.

In the untreated group, at day 2 after inducing tetanic contractions, triceps surae muscle stretching tension values tended to increase again. A study by Ito et al. used a human delayed onset muscle soreness model created with repeatedly induced tetanic contractions combined with rapid transient stretching (eccentric exercise contraction). At day 2 after creation of the
model, the presence of muscle knots accompanying muscle soreness was verified\textsuperscript{14}. The hypertonia model created for this study was subjected to concentric exercise contraction only, so compared to adding eccentric exercise contraction the degree of exercise was mild. However, since there could also have appeared the similar muscle soreness to the delayed onset muscle soreness (DOMS) at around day 2 after, it is conjectured that this could have been accompanied by muscle knots and other changes in muscle tissue that could have influenced triceps surae muscle stretching tension.

This study succeeded in showing that acupuncture stimulation tended to have a relaxing effect on hypertonic muscle but it did not provide any definite proof. Nevertheless, untreated and acupuncture groups had obviously different courses together with almost no individual differences within each group and the same tendencies, the future identical studies should include a larger number of subjects and the statistical significance of the muscle relaxing effect by acupuncture should be verified. Based on the results of such studies, the intention is to move ahead with studies about the mechanism involved in the relaxing effect acupuncture stimulation has on hypertonic muscle.

Conflicts of interest

The authors declare no conflicts of interest.

References

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