ORIGINAL ARTICLE

# The Effect of Electro-Acupuncture on Spasticity of the Wrist Joint in Chronic Stroke Survivors

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ABSTRACT. Mukherjee M, McPeak LK, Redford JB, Sun C, Liu W. The effect of electro-acupuncture on spasticity of the wrist joint in chronic stroke survivors. Arch Phys Med Rehabil 2007;88:159-66.

**Objective:** To quantitatively assess the change in spasticity of the impaired wrist joint in chronic stroke patients after electro-acupuncture treatment.

**Design:** Crossover design.

**Setting:** University medical center research laboratory.

**Participants:** Seven chronic stroke subjects (age, 63.14±7.01y).

**Intervention:** Participants received two 6-week treatment regimens: combined electro-acupuncture and strengthening twice a week, and strengthening twice a week only. Muscle strength and spasticity of the wrist joint were quantified by using the Biodex multijoint System 3 Pro. Electro-acupuncture was given through a commercial electro-acupuncture device.

**Main Outcome Measures:** Velocity sensitivity of averaged speed-dependent reflex torque (VASRT); segmented averaged speed-dependent reflex torque (SASRT); Modified Ashworth Scale (MAS) scores; and integrated electromyographic activity of the affected wrist flexors during passive stretch of the affected wrist joint.

**Results:** VASRT was reduced significantly in the combined treatment group ($P$=.02) after the 6-week period, but not in the strengthening-only group ($P$=.23); however, no significant immediate effect of electro-acupuncture was observed ($P$>.05). MAS scores also showed a significant reduction ($P$<.01). SASRT did not differ significantly across different positions of the joint or across velocity; however, significant differences were present between the 2 treatment groups ($P$<.05) for each position and at all the velocities except at 20°/s. Integrated electromyographic activity showed a trend for reduction after the combined treatment.

**Conclusions:** A combination of electro-acupuncture and muscle strengthening exercise for 6 weeks significantly reduced spasticity. The effect of spasticity reduction was consistent across different joint positions and different velocities of passive stretch.

**Key Words:** Acupuncture; Muscle spasticity; Rehabilitation; Stroke.



SPASTICITY HAS BEEN DEFINED as a motor disorder characterized by a velocity-dependent increase in tonic stretch reflexes (muscle tone) with exaggerated tendon jerks, resulting from hyperexcitability of the stretch reflex, as a component of the upper motoneuron syndrome.[1] Spasticity is a characteristic feature of upper motoneuron syndromes such as stroke and is a potential obstacle to improvements in motor control and functional ability of the upper limb through different rehabilitative techniques.[2] It is estimated that more than half of stroke survivors develop moderate or severe impairment of the affected upper extremity including spasticity.[3]

Acupuncture has been shown to reduce spasticity in both humans and animals.[4-7] Acupuncture treatment, a nonpharmacologic modality with minimal side effects,[8] is a promising modality for stroke rehabilitation; however, most previous studies provide limited objective evidence in describing its beneficial effects in terms of reduction in spasticity after the acupuncture treatment. A systematic quantification of the ability of acupuncture treatment to reduce spasticity is lacking. In addition, a recent study[9] showed that acupuncture led to immediate and short-term plastic brain reorganization in comparison to needling at nonacupuncture points in healthy subjects. Therefore, it would be potentially beneficial to determine through quantitative measurements whether there is an immediate effect after acupuncture treatment on spasticity level in stroke patients.

Several methods have been used over the years for quantification of spasticity. These methods have ranged from subjective measures like the Ashworth Scale to more objective quantifications, such as measuring reflex threshold or reflex gain during pendulum test, sinusoidal excitation, or constant velocity stretch.[10-14] Calibration, however, is complicated in both pendulum and sinusoidal tests.[15] Threshold measurements from electromyographic signal may not give good results because of low activity and high variability.[16,17] The relative reflex torque during passive stretch under constant velocity may be more reliable and clinically acceptable in quantification of spasticity.[15] In fact, such measurements provide a direct quantification of spasticity as defined by Lance.[18]

This report presents a part of the result of a study that compared the effect of a combined electro-acupuncture and strengthening treatment with that of strengthening-alone treatment on the hemiparetic wrist joint of a group of chronic stroke survivors through a crossover design. The purpose of this part of the study was to objectively quantify both immediate and 6-week effects of the electro-acupuncture intervention in managing spasticity. The following 3 hypotheses were tested: (1) the electro-acupuncture treatment would bring an immediate reduction in spasticity; (2) there would be a significant decrease in spasticity of the hemiparetic wrist joints of subjects after the 6-week combined electro-acupuncture and strengthening treatment; and (3) there would be no significant change in wrist

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Table 1: Subject Demographics

| Subject | Age (y) | Sex | Stroke Duration | Type of Stroke | Side Affected (body) |
|---|---|---|---|---|---|
| s1 | 61 | M | 5y | Hemorrhagic | Right |
| s2 | 61 | F | 3y | Ischemic | Right |
| s3 | 58 | M | 12y | Hemorrhagic | Left |
| s4 | 54 | F | 31y | Ischemic | Right |
| s5 | 64 | M | 3y 7 mo | Hemorrhagic | Right |
| s6 | 69 | M | 2y 6 mo | Hemorrhagic | Right |
| s7 | 75 | F | 9y | Ischemic | Left |

Abbreviations: F, female; M, male.

spasticity in subjects after 6-week strengthening treatment alone.

## METHODS

Seven chronic stroke subjects (4 men, 3 women) were recruited for the study. The mean age of the subjects was 63.14±7.01 years (range, 54−75y) (table 1). All the subjects were recruited from the local community, had a documented diagnosis of stroke, and a Modified Ashworth Scale (MAS) score of 3 or over in the wrist joint. The exclusion criteria included: (1) a stroke onset within the previous 3 months; (2) not independent in the basic activities of daily living; (3) unable to follow a 3-step command; and (4) progressive or severe neurologic disease, heart conditions, unstable hypertension, fractures, and/or implants in the upper limb. For cognitive screening purposes, subjects underwent the Folstein Mini-Mental Status Examination; the Florida Apraxia Battery; and the Geriatric Depression Scale. The study protocol and informed consent was reviewed and approved by the human subjects committee of the University of Kansas Medical Center.

This study had a crossover design with each subject undergoing a combined treatment of acupuncture and strengthening exercises (AS treatment) for 6 weeks and a treatment of only strengthening exercises (S treatment) for another 6 weeks. The choice of a crossover design was made to facilitate subject recruitment and also to be compassionate toward all stroke subjects in getting the treatment. The order of the 2 treatments was randomly organized for the subjects. Within the study period, each subject received the treatment twice a week on 2 different visiting days. Activities during a visiting day of the AS treatment phase consisted of 40 minutes of electro-acupuncture treatment followed by 30 minutes of strengthening exercises. During the S treatment phase, only the strength training was conducted.

The protocol used in the electro-acupuncture regimen was based on a previous study.[19] The areas selected for needling were cleaned with 75% alcohol. The needles were single-use, disposable steel acupuncture needles (Seirin acupuncture needles, ISO 9002),[a] with a diameter of 0.2mm and a length of 60mm. The needles were inserted into the following acu-points on the subject's hemiparetic arm: (1) Hegu (LI 4), in the first dorsal interosseous muscle; (2) Houxi (SI 3), at the ulnar aspect of the fifth metacarpophalangeal joint, at the end of the transverse crease and the junction of dorsal and palmar skin; (3) Waiguan (TW 5), 5.1cm (2in) above the transverse crease on the dorsum of the wrist; (4) Quchi (LI 11), on the radial aspect of the elbow at the origin of the extensor carpi radialis muscle and the radial side of the brachioradialis muscle; (5) Shousanli (LI 10), 5.1cm distal to the LI 11 site on the forearm; and (6) Jianyu (LI 15), anterior-inferior to the acromion, on the upper portion of the deltoid muscle. In the process of insertion, the needles were inserted perpendicularly in all 6 acupuncture points, forming a 90° angle with the skin surface. Depth of needle insertion was approximately 10mm for LI 11 and TW 5, and 15mm for all other acupuncture points. After insertion of needles into the tissue, alternating current was passed between the 2 nearest needles (LI 4 with SI 3, TW 5 with LI 11, LI 10 with LI 15) using commercial electro-acupuncture device (model ITO-41070).[a] Current pulses were set at 2Hz. The intensity of current was increased to the point where the patient reported the needling reaction and then it was reduced slightly to an unpleasant but tolerable intensity. The "needling reaction" is the characteristic response of a subject to acupuncture needle insertion and manipulation. The subject reports an acute, strongly aversive sensation that is restricted to the site of needle insertion. After 5 to 10 minutes when the subject became sensitized to the stimulus, it was increased slightly and maintained for 30 minutes. Electro-acupuncture rather than manual acupuncture was used in this study to ensure that all the needle stimuli were handled in the same manner. The subject underwent electro-acupuncture treatment in a sitting position (fig1).

During combined (AS) treatment, subjects performed a strengthening exercise regimen on the Biodex multijoint System 3 Pro[b] after the acupuncture treatment. The exercise regimen included active assisted, isokinetic, and isometric exercises. The exercises were made progressively more difficult to perform along with increases in the subject's muscle strength and active range of motion (AROM). The strengthening exercise was conducted for about 30 to 45 minutes, with rest periods taken whenever necessary. During the strengthening (S) treatment, subjects performed the same strengthening exercise without the acupuncture treatment.

### Exercise Protocol

Subjects who had an AROM less than 30° were put in the type-A exercise group and those who had greater AROM were put in the type-B exercise group. Subjects in type-A exercise group performed active assisted and isometric exercises. Subjects in the type-B exercise group performed isometric and isokinetic exercises. When the AROM of type-A subjects increased to 30° or more, they were put in the type-B group. The following description is for a single set of each type of exercise. Active-assisted exercise consisted of performing 5 repetitions each of wrist flexion and extension exercises while holding the wrist attachment as it moved through flexion and extension at 20°/s. Isometric flexion and extension exercises were performed 5 times each with a contraction time of 5 seconds and a resting period of 10 seconds. Isokinetic exercises consisted of 5 repetitions each of flexion and extension at 5°, 10°, and 20°/s. Five sets of each exercise were performed alternating with the other type. Exercises were made progressively more difficult by increasing the number of repetitions. In the AS group, 3 subjects had wrist extension of 30° or more

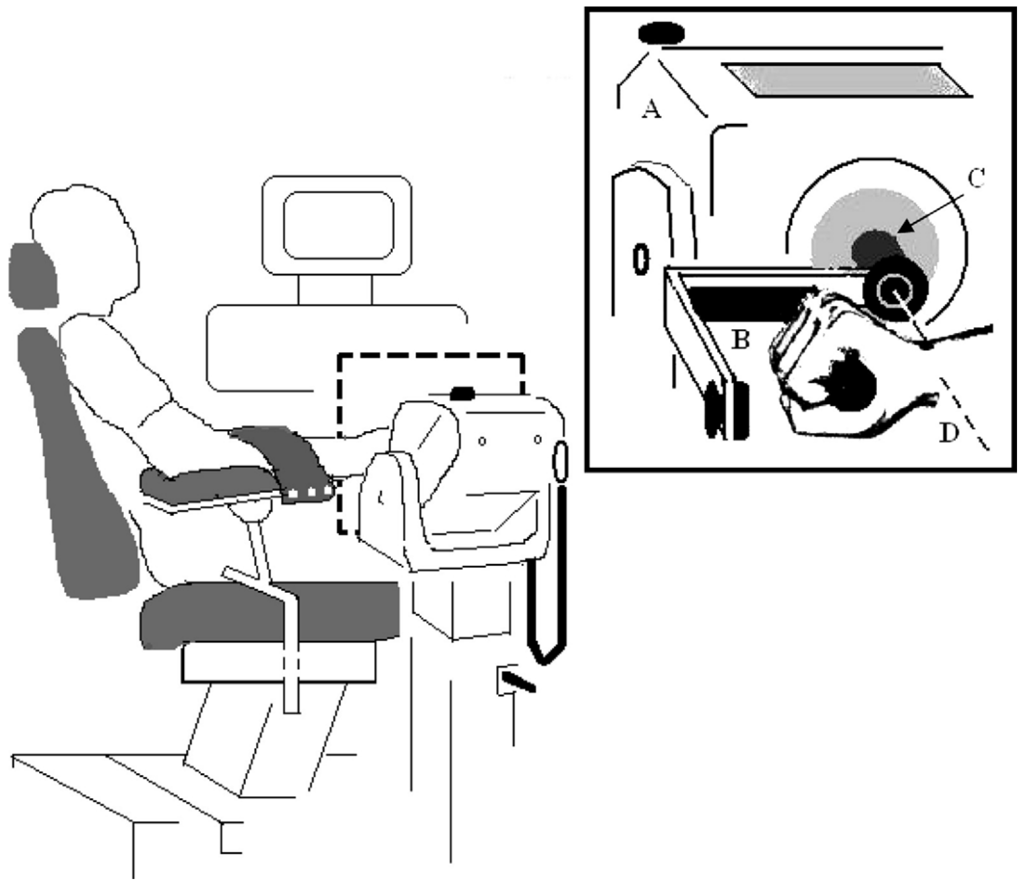


**Fig 1. The position of the subject during testing and training. The dashed square is enlarged and the position of the hand holding the dynamometer wrist attachment is shown. Legend: A, dynamometer; B, wrist attachment; C, crank shaft; D, axis of wrist joint rotation.**

and therefore they began with type-B strength training. The other 5 subjects first began with type-A strength training. Two of these 5 subjects improved their wrist extension range of motion (ROM) beyond 30° before training completion and were shifted to the type-B strength training protocol. In the S group, 3 subjects began with type-A, and the remaining 5 with type-B strength training protocol.

Each subject was assessed before and after each of the 2 treatments. The post-treatment assessment for the first treatment phase was always taken as the pretreatment assessment for the treatment that immediately followed. The assessments of the spasticity level included the following: (1) quantitative measurement of wrist joint spasticity, and (2) MAS scores[20] for the wrist and the index finger flexors and extensors. Quantitative measurement of spasticity was performed according to a previously established procedure[21] with minor modifications. In our procedure, the subject's wrist joint was manipulated passively using the Biodex machine. The test was performed in the sitting position as shown in figure 1, with the subject strapped on to the chair to prevent trunk movement during the experiment. The affected arm of the subject rested on a flat surface attached to the subject's chair so that the shoulder was at about 0° to 5° of flexion and 10° to 15° of abduction. The elbow was positioned at 90° to 100° of flexion. The forearm was strapped on to the resting surface in a prone position. The subject held the wrist attachment of the dynamometer so that its axis of rotation aligned with an imaginary line joining the ulnar and the radial styloid processes (see fig 1 inset). The fingers of the subject were strapped around the handle and therefore only the wrist joint was free to move in a vertical plane. Wrist extension movements were made against gravity and flexion movements toward it. Gravity corrections were performed using the dynamometer software before testing the subject. The subject's wrist was moved passively through flexion and extension at 5 different angular velocities: 5°, 20°, 45°, 60° and 75°/s. At each velocity, the wrist joint went passively from flexion to extension 5 times. During the passive wrist movement, the resistance torque and angular motion of the wrist were recorded through transducers in the machine and stored in a computer. Recorded resistive torque at very slow motion of the wrist joint at 5°/s was taken as the baseline. Figure 2A shows the division of the area between the resistive torque at 5°/s and 45° and 75°/s into 5 segments (I to V) for 1 subject. At each of the following velocities, 20°, 45°, 60°, and 75°/s, the average speed-dependent reflex torque (ASRT) was determined as the difference between the resistive torque at each velocity and the baseline. The slope of the regression line for the ASRT values for the 4 angular velocities was determined as the velocity sensitivity of the ASRT (VASRT). We divided the area between the reflexive torque at baseline velocity and higher velocities into 5 segments in order to determine the position dependent effects of the treatment on spasticity. The area between the reflexive torque at each of the 4 velocities and the baseline torque was divided into 5 equal segments. Each of the 5 segments had a range of 10° because the ROM at which we tested spasticity was 160° to 210° of wrist extension (neutral wrist position, 180°). The segmented ASRT was compared before and after treatment. The detailed definition and data processing procedures can be found in the study by Lee et al.[21] During the test, electromyographic signals from the wrist flex-

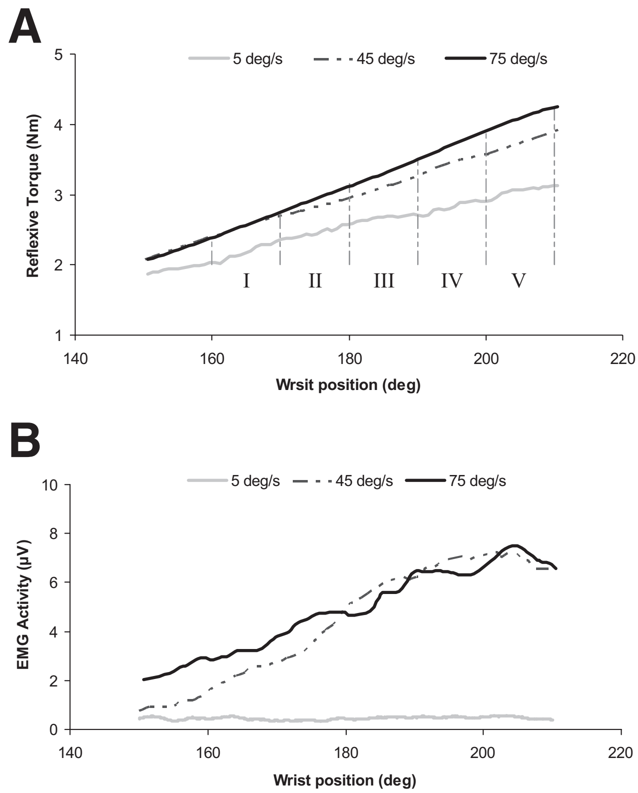


**Fig 2. (A) Data from a stroke subject showing the reflexive torque generated by the subject in response to passive motion of the wrist joint at baseline angular velocity (5°/s) and at 45° and 75°/s. The neutral position for wrist flexion and extension is denoted as 180°. Average reflexive torque values are determined in each of the 5 segments shown in the figure (I to V) and is used in determining the velocity sensitivity of ASRT. (B) Integrated electromyographic (EMG) data of the same subject for the 3 angular velocities (5°, 45°, 75°/s).**

ors and extensors were recorded using the TeleMyo 900 system.[c] Surface electromyography electrodes[d] were attached to the muscle bellies of the wrist extensors and flexors. Raw electromyographic signals, sampled at 1000Hz, were rectified, filtered, and further processed by averaging a 50ms moving window. After subtracting a baseline value (1−100ms prior to movement onset) from the experimental data, the integrated value of the specific movement range was obtained for each trial. Figure 2B shows the integrated electromyographic activity during 5°, 45°, and 75°/s passive motion of the same subject as figure 1A. A movement range of 50° was determined for each subject through passive extension of the wrist joint. A 40ms electromechanical delay between electromyographic activity and torque production was considered while processing data within this ROM. Electromyographic activity was processed in the region between 40ms before the onset and 40ms before the end of the 50° range of passive stretch.

To examine the immediate effect after acupuncture, additional quantitative measurements of spasticity were performed once a week during the AS treatment phase. On those specified days, spasticity was tested before and immediately after the completion of the electro-acupuncture treatment. The strength training then followed. Dependent variables in this study included VASRT, position sensitivity of averaged speed-dependent reflex torque or segmented ASRT (SASRT), MAS score, and integrated electromyographic activity of the affected wrist flexors during passive wrist extension. To examine the immediate effect, repeated-measures analysis of variance (ANOVA) was performed using testing time as the repeated factor and paired differences, pre- and postacupuncture treatment as the dependent variable. The treatment effect on SASRT was determined using repeated-measures ANOVA with ASRT segments as the within-subjects repeated factor with 5 levels and treatment and velocity as the 2 between-subjects factors with 2 and 4 levels, respectively. Post hoc measures were performed to look for localized significant differences. Student paired *t* tests were used to determine the long-term effect of the electro-acupuncture treatment on spasticity.

## RESULTS

There was no significant reduction ($P=.60$) in VASRT for the mean immediate effect of the acupuncture treatment determined through repeated measures (fig 3). The change in VASRT values before and immediately after the acupuncture treatment was not consistent over the 6-week period. The VASRT values before and after the two 6-week treatment regimens for each of the 7 subjects are shown in figure 4. All subjects receiving the AS treatment between visits 1 and 13 show a reduction in spasticity except one, who did not show much change; however, of the 2 subjects receiving the AS treatment between visits 13 and 25, one showed an increase, whereas the other one showed a reduction, in VASRT. The effect of exercise-only training is not very clear, with 1 subject showing an increase and another, a decrease in VASRT between visits 1 and 13. Between visits 13 and 25, 3 subjects showed a decrease and 2 subjects, an increase in VASRT.

The measurement on long-term effect revealed that the VASRT had a significant ($P<.05$) reduction before and after the 6-week regimen of combined acupuncture and strength training (AS phase) program (fig 5A). The effect of strength training alone (S phase) on the VASRT was not significant. The MAS score showed a significant reduction after the AS phase ($P<.01$), but not the S phase (fig 5B).

Position-dependent effects were analyzed using the SASRT measure. Figure 6 shows pre and post combined treatment (AS) effects on ASRT in each of the 5 segments at each of the 5 different velocities. Repeated-measures ANOVA did not reveal a significant effect of position or velocity but there was a

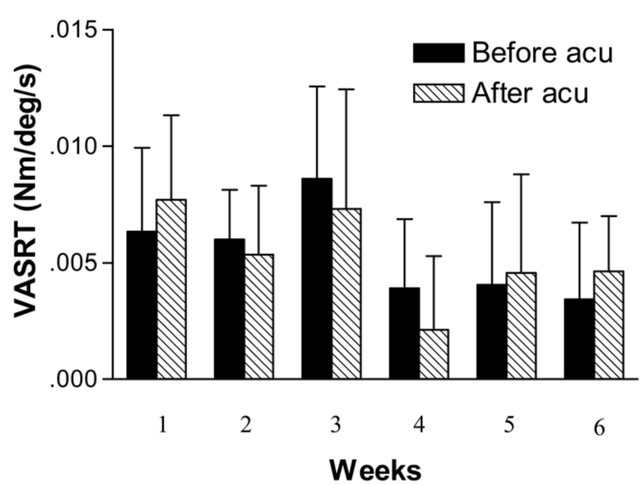


**Fig 3. The immediate effects of the acupuncture (acu) treatment. Mean VASRT values before and immediately after the acupuncture treatment for each of the 6 weeks of treatment is shown.**

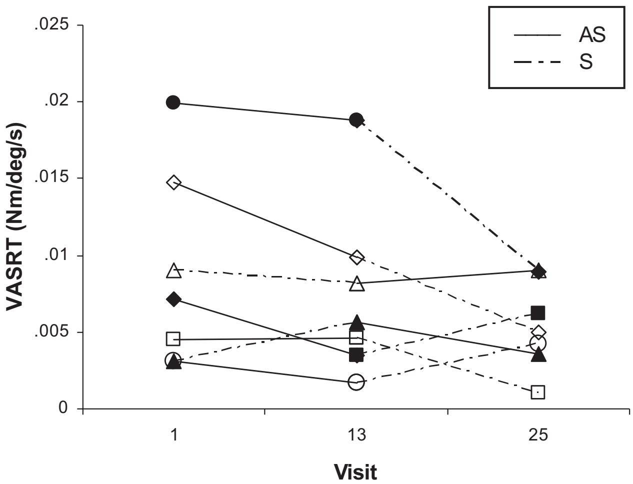


**Fig 4. The VASRT values at each of the 3 time points before and after the 2 treatment regimens for each of the 7 subjects. These time points were the 1st, 13th, and the 25th visits. Solid lines represent the combined treatment (AS) and broken lines represent the strengthening treatment (S).**

indicates a neurologic mechanism of spasticity reduction through acupuncture. There is also the possibility of the reduction in spasticity being the result of alterations in the physical properties of the affected connective tissues around the wrist joint.[23-25] These results further support the finding of reduced spasticity after the combined electro-acupuncture treatment and strength training using quantitative spasticity measurements.

The reduction in the spasticity level after the combined treatment in this study was unlikely to be the result of strength training. This study had a crossover design, in which each subject went through 2 phases, a combined treatment, and strength training alone. The order of the 2 treatments was randomized. The reduction in spasticity was observed only after the combined treatment. In fact, the mean value of spasticity measured quantitatively increased slightly after the strength training phase. Therefore, the electro-acupuncture treatment was most likely the cause of the reduction in spasticity. A clear picture is difficult to discern from the individual subject data presented in figure 4, probably because, in spite of randomization, there were fewer subjects who started with the exercise treatment than with the combined treatment. This is also the probable reason why the baseline value of VASRT

significant effect of treatment ($P<.05$). Post hoc tests showed that significant treatment differences (between AS and S groups) were present in each of the 5 segments for angular velocities of 45°, 60°, and 75°/s.

The electromyographic signals recorded from 2 subjects were incomplete due to technical problems and therefore excluded from the data analysis. The integrated electromyographic activity from the remaining 5 subjects in the wrist flexors during passive wrist extension was not found to be significantly different before and after the AS phase at any of the 5 angular velocities ($P>.05$); however, electromyographic data were available from only 5 of the 7 subjects and there was high variability in the data as well. Figure 7 shows the integrated electromyographic activity of the wrist flexors at the 5 different angular velocities. A decreasing trend was observed pre- and posttreatment at each of the 4 angular velocities (20°, 45°, 60°, 75°/s).

## DISCUSSION

The major finding of this study was a significant reduction in spasticity after a 6-week electro-acupuncture and strength training using quantitative measurements. Some previous studies[4-7] have shown the effect of acupuncture treatment on the reduction in spasticity using clinical measurements. In the study by Fink et al,[22] acupuncture was found to have no effect in treating muscle spasticity. The acupuncture treatment in their study involved only inserting needles, without any needle manipulation or electric stimulation. In our study, electric stimulation was applied through the needles inserted into the subject's skin at the acupuncture points. The subjects in the Fink study were treated in the lower limb, which had pes equinovarus deformity. These differences may partially contribute to the discrepancy in results between our study and the Fink study. The clinical measurement using MAS scores showed a similar reduction like the quantitative measurement in our study. Furthermore, flexor muscle activities during passive wrist extension, as measured by muscle electromyographic signals, showed a decreasing trend after the combined treatment (see fig 7). Despite the small sample size and a high degree of variability in the electromyographic data, this trend

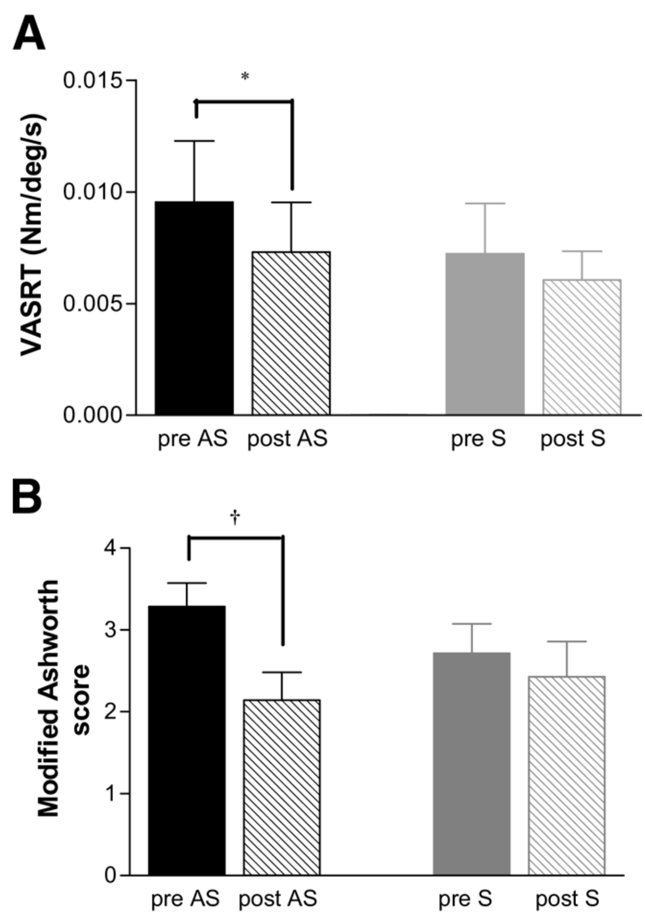


**Fig 5. (A) VASRT values before and after the combined acupuncture and muscle strengthening treatment (pre AS and post AS, respectively) and before and after only the strengthening exercise treatment (pre S and post S, respectively). *$P<.05$. (B) Mean MAS scores of wrist flexors before and after the combined treatment (pre AS and post AS, respectively) and before and after only the strengthening exercise treatment (pre S and post S, respectively). †$P<.01$.**

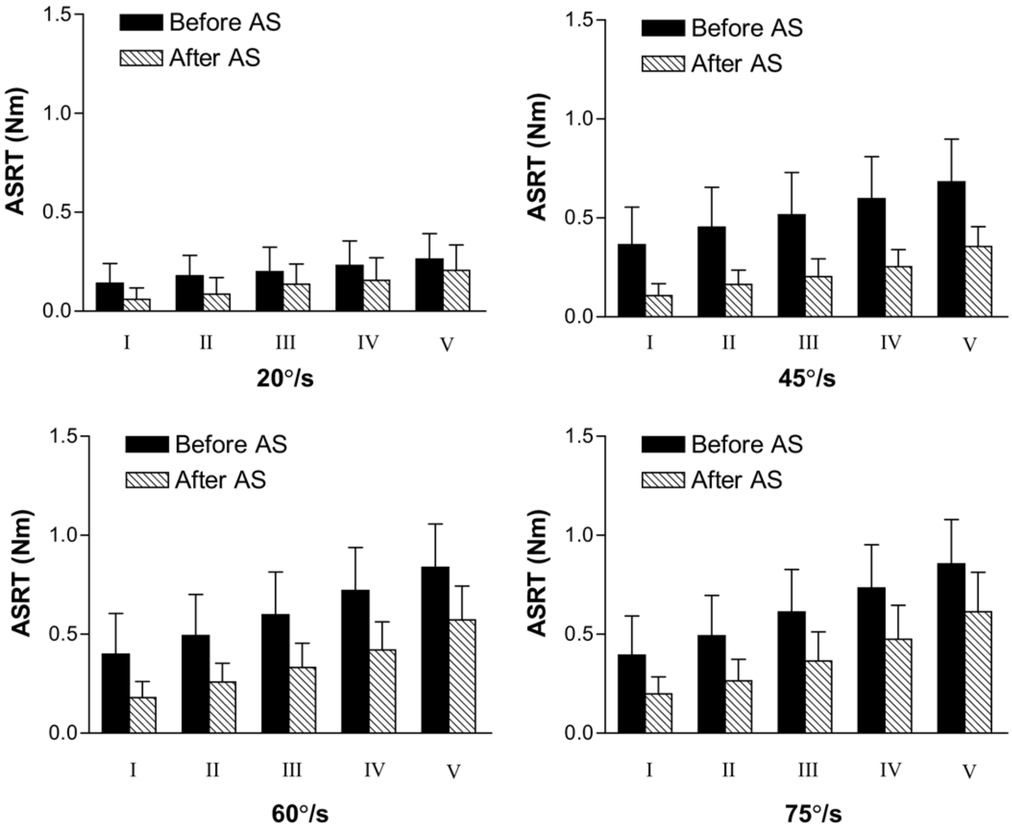


Fig 6. SASRT values during passive wrist extension at 4 different angular velocities before (black bars) and after (hatched bars) 6 weeks of the combined treatment (AS).

before exercise (pre S in fig 5A) is lower than the baseline value before the combined treatment (pre AS).

It has been shown previously that spasticity is not only velocity dependent but also position dependent.[21] In the same study, stroke subjects were shown to have ASRT measures that increased with the joint angle during passive stretch. This position dependence or SASRT was not significant for the Parkinson's patients or for healthy subjects. We found a similar effect of position on spasticity at each velocity; however, we were interested to see if the treatment had a significant effect at all positions of the joint or only at some positions. When paired treatment differences were looked at in each segment, we did not find significant differences. Therefore the combined treatment has a position independent effect on the spastic joint. This effect was present at all the angular velocities; however, there was a significant difference when pre- and post-treatment differences were compared for the 2 groups. This shows that reduction in spasticity was probably caused by the electro-acupuncture treatment and not by the exercise treatment.

The lack of a significant immediate effect after the electro-acupuncture treatment on the reduction of spasticity may indicate that a relatively long period of time is needed for such an effect to be detectable. Similar findings have been reported in an earlier study[26] in which H-reflex changes after electro-acupuncture were found to be insignificant. These preliminary data may suggest that electro-acupuncture stimulation has minimal effect for any long-lasting changes in the spinal reflex pathway, even though more studies are required to confirm such a speculation. The ability of acupuncture to bring about cortical changes has been demonstrated through transcranial magnetic stimulation in healthy subjects.[9] A 10-minute acupuncture stimulation procedure produced significant immediate changes in the cerebral cortex activity from the baseline. The amount of cortical plasticity observed by Lo et al[9] may not be enough to trigger significant reduction in spasticity immediately, but the effect may accumulate over longer periods of time to cause significant changes. The findings in our study support such a view. It may be important to remember that the lack of an immediate reduction in spasticity in our study indicates the immediate effect on spasticity after removing the

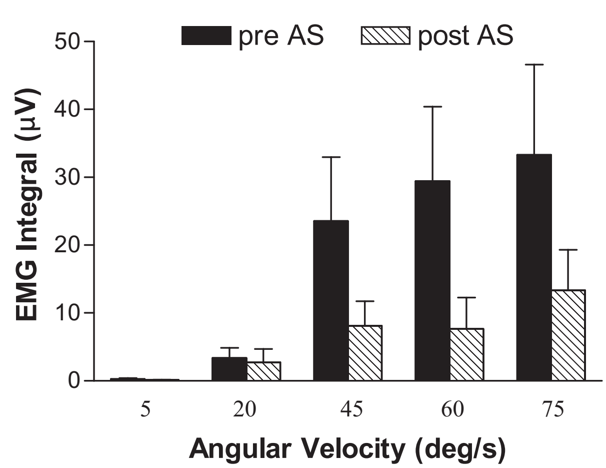


Fig 7. Mean integral electromyographic activity of the wrist flexors during passive wrist extension at 5 different joint angular velocities before and after 6 weeks of the combined AS treatment.

needles, but not when the needles were in the skin. Anecdotal clinical experience suggests an observable reduction in spasticity while the acupuncture needles were inserted alone or along with electric stimulation applied to the patients. In the present study, quantitative measurement of wrist spasticity was conducted only after the completion of the electro-acupuncture treatment and removal of all needles. This decision was based solely on the safety concern of subjects in order to avoid any potential damage to skin and/or muscle when passively moving the subject's wrist with needles inserted in the skin.

In our study, the velocity-dependent resistance was quantitatively evaluated and changes were examined as indicative of changes in the spasticity level, as defined by Lance.[18] The velocity-dependent resistance has both neurologic and nonneurologic components.[27] A decreasing trend observed in electromyographic data recorded from wrist flexors during wrist extension movement during pre- and posttreatment testing may indicate the influence of electro-acupuncture treatment on the neurologic component of spasticity, that is, the reduction in hyperreflexia. Increased motoneuron excitability is considered to be one of the main reasons behind the occurrence of spasticity. This could be caused by increased excitatory synaptic input,[28] reduced interneuron inhibition,[29] or alterations in the intrinsic neuron properties.[30] Acupuncture may change the motoneuron activity and/or change synaptic transmission from muscle afferent terminals to spinal motoneurons, presumably mediated by presynaptic interneurons, and change intrinsic motoneuron properties, including membrane input resistance or membrane receptor responsiveness to released transmitters. These possible mechanisms of reducing spasticity have been brought into consideration in a previous study.[31] The study showed that c-*fos*, a proto-oncogene in neuronal cells in the spinal cord of rats, is expressed rapidly in the presence of a noxious stimulus given alone or with electro-acupuncture and naloxone (an opiate receptor blocker). On the other hand, with electro-acupuncture, protein expression in the presence of the noxious stimulus is significantly reduced. In our study, the amount of neurotransmitter released by electro-acupuncture may not be above the threshold required to produce a significant reduction in spasticity within a short time period (30min), whereas the cumulative effect, over a period of 6 weeks, may be the reason for significant spasticity reduction. Acupuncture has also been shown to suppress the amplitude of somatosensory evoked potentials in both humans and animals.[32-34]

### Study Limitations

There are some limitations in our study. The examiner was not blinded to the subject's trial-to-trial variations and therefore the testing results could have been influenced by human bias. The human bias, however, may be minimized in quantitative measurements because the Biodex machine was used to conduct the test and data collection. Second, no control group of subjects was introduced and the sham acupuncture procedure was not used in the strength training phase. Therefore there is no guarantee that the placebo effect of the electro-acupuncture treatment had been removed completely from the results, even though the crossover design of taking subjects as their own control might reduce the placebo effect.

## CONCLUSIONS

There was a significant reduction in spasticity after a 6-week electro-acupuncture and muscle strength training and such a reduction was most likely due to the electro-acupuncture effect. Because there was no immediate effect in reducing spasticity through acupuncture intervention, further studies are needed to quantify this cumulative effect and explore the probable underlying mechanisms.

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