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Innovative Tone Normalization Therapy Improves Persistent Contracture in the Non-functional Hand: A Case Series

Liang L[1], Saunders-Newton C[2] and Sanossian N[3]*

[1]Department of Occupational Therapy, Keck Medical Center of USC, University of Southern California, USA

[2]Department of Occupational Therapy and Occupational Science, University of Southern California, USA

[3]Department of Neurology, Medical School of University of Southern California, USA

Abstract

Objective: To describe a novel treatment for improving non-functional hand function in participants with chronic (two to eight years) spasticity that failed conventional inpatient and outpatient rehabilitation.

Methods: Three participants with history of chronic hand contracture from neurological disease were recruited from an outpatient rehabilitation setting at a university hospital. Innovative Tone Normalization Therapy (ITNT) was administered at sixty minutes per session, once or twice a week; range from 14 to 31 sessions. The primary outcomes were change in Tardieu Scale - Quality of Muscle Reaction (QMR), shortened Disabilities of Arm, Shoulder and Hand (Quick-DASH), Box and Blocks Test (BBT), Goniometry, Manual Muscle Test, and Observation of hand function [1-3].

Result: All three cases demonstrated significant decrease in spasticity in the targeted hand with corresponding improved function, as measured by increased Active Range of Motion (AROM) and strength, and improved Quick-DASH, BBT and hand function.

Conclusion: For participants who failed conventional therapy to reduce spasticity, ITNT, when integrated into a multifaceted approach for reducing spasticity improved recovery of voluntary motor action.

Keywords: Contracture; Spasticity; Muscle memory; Splinting; Mirror therapy; Qigong

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Correspondence:
Liang L, Department of Occupational Therapy, Keck Medical Center of USC, University of Southern California, 1520 San Pablo Street, Los Angeles, CA 90033, USA, Tel: (323) 442-8500-60115; Fax: (323) 442-8528; E-mail: Linda.Liang@med.usc.edu

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Introduction

Contractures are characterized by shortening and hardening of muscles, tendons, and other soft tissues, potentially leading to deformities and rigidity of joints [4]. Contractures affect hand joint mobility, interferes with motor recovery, hand function, hygiene, lifestyle and ability to participate in meaningful activities. Additionally, the presence of contractures is associated with higher levels of disability [5]. Within the context of upper motor neuron lesion, contractures develop as a sequelae of abnormal muscle activity associated with spasticity. As defined by the Program Support for Assembly of a Database for Spasticity Measurement (SPASM), spasticity is characterized by "disordered sensory-motor control resulting from an upper motor neuron lesion, presenting as intermittent or sustained involuntary activation of muscles" [6]. Nearly one third of stroke patients go on to develop spasticity resulting in a loss of hand function. Residual spasticity occurs in approximately 19% to 38% of stroke patients with upper limb spasticity more prevalent than lower limb spasticity [7,8]. Approximately 30% of stroke survivors report problematic spasticity that interferes with function [9]. The prevention and treatment of contractures and spasticity are very important aspects of rehabilitation for acquired brain injury [10]. Non-invasive conventional rehabilitation strategies used to manage spasticity and contracture include splinting, stretching, electrical stimulation and exercise approaches. Although stretching of the involved muscle is one of the more commonly used non-drug interventions for the management of spasticity. There is minimal effect on spasticity [11]. Splinting used alone or in conjunction with electrical stimulation had shown minimally reduced spasticity [10,12,13]. Exercise is commonly used to improve motor control and strength, without worsening spasticity [11]. While exercise has been proven to be beneficial in this regard, there is little evidence that exercise decreases spasticity. Research in the benefits of electrical stimulation in the treatment of contractures failed to demonstrate improvement [4]. Current interventions have a limited impact on the problem of spasticity and contractures, consequently individuals with chronic neurological deficits continue to report significant rates of a non-functional hand. We developed and applied a novel treatment method, Innovative Tone Normalization Therapy (ITNT), to manage spasticity in three participants with a non-functional hand due to chronic neurological deficits.

Method

Research design

The ITNT was developed by the first author (L. L.). We report a qualitative description on three consecutive participants with whom ITNT was applied. All three participants were referred to the occupational therapy clinic. All treatment was administered at the outpatient rehabilitation at a university hospital in the time period from 2018 and 2019. Informed, written consent was obtained from all participants.

Participants

Prior to receiving ITNT, all three participants received conventional interventions including splinting, passive stretching, and electrical stimulation for severe contracture of the unilateral hand. Participant 002 also received constraint-induced movement therapy facilitated by casting of the intact arm. Study participants were selected for unilateral hand contracture from neurological deficits, sufficient cognitive function to understand the treatment method (Montreal Cognitive Assessment score above 21 of 30 points), and were agreeable to follow the ITNT treatment plan. Additionally, each of the participants failed conventional rehabilitation for the treatment of hand contractures. Three conditions excluded participants from receiving ITNT; acute neurological deficits, no conventional methods attempted, contractures resulting from etiology other than a neurological condition, or if the participant declined to follow the ITNT protocol.

Outcome measures

Assessments of results were obtained through the Tardieu Scale - QMR, Quick-DASH, BBT, Goniometry, Manual Muscle Test and observation of hand function. The Tardieu Scale-Quality of muscle reaction is used to describe spasticity. It is based on a 6-point scale, from 0 to 5: 0= no resistance throughout the course of the passive movement; 1= slight resistance throughout the course of the passive movement, with no clear catch at a precise angle; 2= clear catch at a precise angle, interrupting the passive movement, follow by a release; 3= fatigable clonus (<10 seconds when maintaining pressure) occurring at a precise angle; 4= infatigable clonus (>>10 seconds when maintaining pressure) occurring at a precise angle; 5= immobile [14]. The BBT was developed to quantitatively measure manual dexterity. Administration takes one minute and does not impose a burden on patients with neurological deficits. The BBT consists of a box with a center partition. Small wooden blocks are placed in one side of the partition. The other side of the partition is empty. Participants are asked to pick up blocks, one at a time, and drop them on the other side of the partition. The BBT score represents the number of blocks transported in sixty seconds. The Disabilities of the arm, Shoulder and Hand (DASH) questionnaire is a patient reported outcome measure of upper extremity function. The Quick-DASH is a shortened form of the DASH: Rather than 30 items, the Quick DASH consists of 11 items. The Quick-DASH is more appealing because it can be administered in a shorter time and is less stressful to chronic neurological patients.

Intervention

Each participant received sixty minutes per session, once or twice a week, and range from 14 to 31 sessions. None of the participants received any other interventions other than ITNT provided by the first author. The ITNT is a progressive process that depends on three key principles: (1) Relaxation of tone to achieve hand functional position; (2) use of sectional orthotics/splints combined with stretching to improve PROM; and (3) facilitation of muscle memory.

Relaxation of tone with goal of achieving hand functional position

To facilitate relaxation, qigong and mirror therapy techniques were applied. All participants were trained on qigong and mirror therapy as a daily home program. Mirror therapy was not only used as a home program but also used for five to ten minutes in the beginning of each treatment session. Unique to ITNT, after improvement in relaxation, the affected hand is positioned on a ball to increase web and finger spaces in a functional position and to prepare the hand for optimal movement. Participants were instructed to direct attention away from the hand when moving the affected hand.

Use of sectional orthotics/splint combined with stretching

Rather than using a traditional resting splint, the first author constructed a series of smaller sectional splints that covered only a part of the hand or the wrist. Multiple sectional splints were constructed: Volar wrist splint for wrist extension, web space splint to increase web space, palm splint to open palmar area of the affected hand. Participants were instructed to place sectional splints for one to two hours at a time and then to stretch their joints with PROM. After sectional splinting, stretching and PROM, participants were instructed to keep the affected hand on a small ball to facilitate a functional hand position.

Facilitation of muscle memory

The next step was to progress toward continued dampening of flexor tone in order to facilitate muscle memory. Working in a sequential manner, with improved relaxation and PROM, the affected hand is placed on a ball in a functional position. The participants then worked on maintaining the hand on the ball in a functional position, and then worked on active wrist extension, followed by ulnar/radial deviation. Participants then placed the affected elbow, forearm and hand on a low table and relaxed until extended by gravity. After full extension was achieved, participants began to work on wrist flexion/extension in a gravity eliminated position. With voluntary movement improved, treatment shifted toward greater AROM and strengthening. A relaxation program was used as needed to manage the tone. As soon as possible, familiar unilateral and bilateral priming accelerated recovery of hand function was introduced such as self-feeding, putting tooth paste on a tooth brush, and folding clothes. When performing familiar upper limb activities, participants were instructed not to pay attention to the affected hand and only maintain attention to the tasks.

Data collection

All participants were treated by the primary occupational therapist (L. L.), who carried out the assessments and intervention. The evaluation, and outcome measured used the same assessment tools. A secondary therapist was present to gather and assist in

Table 1: Results of ITNT for three participants.

Participants		001		002		003	
Years of spasticity before ITNT		8		8		2	
Number of Sessions		31		27		14	
Improvement	Tardieu Scale-QMR	4	1	4	0	3	0
	AROM	No AROM	Nearly full hand extension with 3 cm web space	No AROM	Full AROM	No AROM of thumb/finger extension	Full thumb/finger extension
	Strength	0/5	2+ - 3+/5	0/5	3+ - 4/5	0/5 (wrist & finger extension)	3+ - 4+/5
	BBT	Unable	7 per minute	Unable	7 per minute	Unable	18 per minute
	Quick-DASH	70.5	47.7	61.4	25	50.06	27.3
	Observation of Hand function	Non-function	Able to do basic ADL like feeding & bilateral daily activities	Non-function	Able to write	Non-function	Able to drive

recording the data on a standardized form.

Results

The medical history for all three participants is summarized below:

Participant 001

A 30-year-old male had a diagnosis of ruptured Anterior Cerebral Artery (ACA) aneurysm and subsequent subarachnoid hemorrhage in January 2010. The aneurysm was treated unsuccessfully with coiling in February 2010 and November 2010, necessitating craniotomy and clipping. One day after surgery, he suffered a right Middle Cerebral Artery (MCA) stroke resulting in left hemiplegia. Following the stroke, there was minimal improvement of the hemiparesis with development of severe and unrelenting spasticity. Subsequently, the spasticity was treated with Botox injections in the left arm, followed by implantation of an intrathecal baclofen pump. From 2010 to 2018, he received multiple in-patient, outpatient, and home health rehabilitation interventions. In 2017, he was told by therapists that the left wrist and hand contracture were no longer treatable. The participant presented to therapy with left chronic upper and lower extremity spastic hemiparesis and severe flexor contractures of the wrist and hand. Sensory testing indicated intact light touch, pain and temperature perception. He was treated with ITNT one session a week, for a total of 31 sessions.

Participant 002

A 14-year-old female had a diagnosis of brain tumor when she was five years old. She underwent brain tumor resection in August 2010 and in April 2014. Since 2010 she experienced right extremity weakness with contracture in the wrist and hand. She received rehabilitation from 2010 to 2018 at multiple pediatric rehabilitation settings with no significant improvement of severe right-hand contracture. The participant presented with right shoulder, elbow and hand weakness; severe wrist and hand flexion contracture, and with impaired light touch, pain, temperature, and stereognosis perception. Of note, she presented with intact proprioception perception. She was treated with ITNT two sessions a week, for a total of 27 sessions.

Participant 003

A 24-year-old male had a diagnosis of hypertension and subsequent stroke on March 2017 resulting in right side hemiparesis and severe spasticity which evolved into a non-functioning hand. At another hospital, he received conventional rehabilitation from March 2017 until April 2019 without recovery of right-hand function. He presented with spasticity in the right hand, especially the right thumb, Index Finger (IF) and Middle Finger (MF), with intact light touch, pain, temperature, stereognosis, and proprioception perception. He was treated with ITNT one session a week, for a total of 14 sessions. Prior to ITNT, participants 001 and 002 each experienced 8 years of spasticity, while participant 003 had 2 years of spasticity. After ITNT, participants 002 and 003 had completely resolved chronic spasticity, while participant 001 retained mild spasticity. All three participants demonstrated significantly improved hand function (Table 1).

Figure 1: Participant 001 with severe left-hand contracture at beginning of intervention.

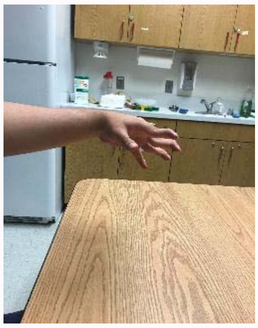

Figure 2: Participant 001 able to perform wrist and finger extension after 20 sessions of ITNT.

Discussion

The ITNT approach utilizes the sequential application of qigong exercises, mirror therapy, hand relaxation positioning, and sectional splinting instead of traditional resting hand splinting. Goals are stretching of affected muscles and use of functional hand activities that leverage selective attention. Central to this approach is an understanding of muscle memory theory. Muscle memory is generated from the acquisition of myonuclei. Murach observed that "Myonuclei acquired from satellite cell fusion during hypertrophic growth remain after detraining when muscle returns to its pre-training state" [15]. Myonuclei is not lost with disuse but serves as the mechanism for muscle memory [16]. Muscle memory can be best described as a type of movement with which the muscle becomes familiar over time. Even without thinking, the relevant muscles become completely accustomed to a familiar movement [17]. It has been posited that muscle memory might be very long lasting in humans, as myonuclei are stable for at least 15 years and might even be permanent [18]. According to the ITNT approach muscle relaxation allows activation of muscle memory through access to previously acquired myonuclei.

Qigong is a deep relaxation technique. Qigong is an ancient Chinese integrated mind-body healing method that uses qi, the life energy that registers as 1.9 mm microwave to promote self-healing [19-21]. The self-healing process is related to a "downshift" Electroencephalographic (EEG) wave from beta waves to alpha waves, theta waves, or a combination of the two. In studies, after three or four minutes of qigong exercises, EEG results demonstrated high-amplitude alpha waves and a measurable shift of alpha and theta concentration from the rear occipital regions to the frontal lobe regions of the brain [22,23]. Mirror therapy was used as both a relaxation technique and to recover motor function. We found that after five minutes of mirror therapy, all three participants demonstrated decreased spasticity of hand and wrist. Additionally, studies show that the mirror neuron system interacts with vision, proprioception and motor commands, promoting the recruitment of mirror neurons and the cortical reorganization and functional recovery of post-stroke patients [24, 25]. Mirror therapy is an easy and low-cost method to improve motor recovery of the upper limb [26,27]. Mirror therapy when combined with bilateral arm training and graded activities was effective in improving motor performance of the paretic upper limb after stroke compared with conventional therapy without mirror therapy [28]. Facilitating motor recovery on the ball was beneficial for two reasons. First, the ball supported the hand in a functional position thereby preparing the thumb and fingers for functional movement. Second, the active movement over the ball reduced gravity to allow greater ease of active assistive range of motion. Therefore, it was easier to initiate movement. In current practice, therapists typically instruct patients to facilitate movement by attending to the affected hand, despite the quality of tone. Our observation revealed that attention directed to the affected limb is associated with increased flexor tone. Current neuroscience research has not addressed this phenomenon.

According to research, resting wrist and hand splints, used alone or in combination with other strategies, were not effective in reducing abnormal tone. Based on conventional understanding of hypertonicity, patients are required to tolerate static splints at least 6 hours a day, however, due to pain and discomfort, Andringa found that patients with severe hand contractures were not able to tolerate this length of time [29]. Due to the lack of evidence that full wrist and hand splinting reduces spasticity sectional splinting was used in a unique way [12,13]. The rationale for sectional splints was that they were easy to apply, were better for prolonged stretching, and facilitated functional hand position. The use of splints was always followed by manual stretching and PROM exercises. We found that the web space sectional splint was the most effective splint for recovery of hand function due to preparation of thumb movement. After the familiar hand movements were initiated, intervention emphasis shifted to traditional methods to improve hand function.

Limitations and Further Research

The ITNT was able to reduce spasticity in non-functional hand due to chronic neurological diseases in this small case series. The results suggested that a multifaceted strategy for reducing spasticity meaningfully improves the recovery of voluntary motor action. However, the limitation of ITNT is that it is an intensive program which requires many one-on-one treatment sessions, needs a dedicated and trained therapist, and needs participants' understanding and compliance. Future studies will need to closely examine the effects of different dosage and treatment duration in preparation for a randomized clinical trial study. The results of these cases warrant investigation of use of this method across different types of upper motor neuron injury.

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