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The Effect of Different Types of Resting Hand Splints on Spasticity and Hand Function among Patients with Stroke

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Abstract: *After stroke, these changes consequently result in the limitation of upper limb joint range of motion or muscle shortening, and spasticity, causing the reduction of hand functions. This study aimed to investigate the effect according to the types of resting hand splints, particularly the effect of the application of resting hand splint. This study was performed in two groups, which were determined by random assignment according to the order of visits of 52 subjects who were diagnosed of stroke. The patients were divided into a dorsal resting hand splint group (n=26) and volar resting hand splint group (n=26). The data collected in this study was analyzed using SPSS version 18.0.For the difference in Modified Ashworth Scales (MAS), surface ElectroMyoGraphy (sEMG), and Wrist Active Range of Motion(AROM) before and after the intervention in two groups, paired t-test was performed, and independent sample t-test was performed to compare the change(s) before and after the intervention in two groups. Statistical significance level was α=.05. First, there was a significant difference in wrist MAS, AROM, and sEMG in the group of dorsal resting hand splint. Second, there was no significant difference in wrist MAS and AROM in the group of volar resting hand splint, but there was a significant difference in wrist sEMG. Third, there was a significant difference in wrist MAS and AROM in the group of resting dorsal hand splint as a result of comparing change(s) between two groups, but there was no significant difference in wrist sEMG. Through this study, it was found that dorsal resting hand splint was more effective in the reduction of wrist spasticity and improving AROM than volar resting hand splint in stroke patients. Applying resting hand splint to stroke patients would not only have preventive effects but also have great influence on the improvement of hand function.*

Keywords: Range of Motion Stroke, Resting Hand Splint, Spasticity, Surface Electromyography

Introduction

When patients experience hemiparesis after stroke, they generally have limited range of motion (ROM) due to upper limb muscle weakness and reduced hand function Kogler GF *et al* (2002), and have problems in functional activities due to neurological and non-neurological changes related with motor control Dietz, V *et al* (2007). These changes consequently result in the limitation of upper limb joint ROM or muscle shortening Foran JR (2005), O'Dwyer, N. J *et al* (1996) and are associated with spasticity, causing the reduction of hand functions such as stretching,grabbing, manipulating, and releasing R. Boyd *et al* (2001). Also, patients have impairment of activities of daily living (ADLs) due to spasticity, pain, and edema, and disfigurement of body image may be caused. It has been known that patients experiencing physical changes like these experience psychological disorders such as depression Robinson RG (1983), Pizzi A (2005), Burge E *et al* (2008) or decreased quality of life Delcourt C *et al* (2010). From this perspective, not onlyimproving upper

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limb function and spasticity prevention and treatment but also postural control and alignment, muscle stretching and improving joint ROM are significant goals for treatment Elovic E *et al* (2005).

The most commonly used rehabilitation program to enhance upper limb function, prevent spasticity and improve joint ROM is hand splint intervention. Its purpose includes spasticity reduction, prevention of muscle contracture, enhancement of functional motions, pain reduction, stretching shortened muscle and edema prevention Williams Pedretti L (1996), Milazzo S (1998), Wilton JC *et al* (1997). However, splint application has still been historically debatable among rehabilitation specialists Edwards S *et al* (1996). This is due to lack of scientific evidence of splint application McPherson JJ *et al* (1982). Nevertheless, splint application is often used clinically for the treatment of upper limbs of patients with hemiparesis Kogler GF *et al* (2002). The evidence of clinical effort to reduce spasticity as well as muscle contracture by applying resting hand splint is that it is possible through applying low-load intensity to hypertonic muscle in a fixed posture or prolonged stretching. The purpose of stretching is to reduce spasticity by inhibiting the activation of reflexive alpha motor neuron and blocking a major cause of spasticity and contracture Gracies J M *et al* (2005). Also, plasticity is promoted by fixing the length of loosened muscle in that conditionand accordingly contracture reduction can be achieved Kottke F J *et al* (1996). Therefore, it has been reported that applying resting hand splint results in the reduction of stiffness and improvement of joint ROM, and the extent varies by application period and measurement method Sheehan J L *et al* (2006). Also, it has been reported that applying resting hand splint for longer than 90 minutes daily has the effects of not only improving wrist ROM or spasticity reduction but also the reduction of pain or spasm Pizzi A *et al* (2005).

Unlike this, there is a report that the improvement of wrist ROM, pain and upper limb function have not been observed although resting hand splint has been applied to the wrist without active motion or the reduction of finger contracture Lannin N A *et al* (2007). Also, effects were not observed in the study with a group of wrist neutral posture, a group of wrist extension at 45°, and a control group Lannin NA *et al* (2003). From this perspective, there is even an argument that it is inappropriate to apply hand splint clinically Lannin NA *et al* (2003).However, because hand splint can be applied not only to volar but also the dorsal of hands, it is possible to argue that the effects can vary depending on a type Pitts DG (2008), Lannin NA *et al* (2003). It has been argued that volar resting hand splintis effective to support hypotonic wrist and a hand, and dorsal resting hand splint provides proper dorsiflexion to wrist and fingers and thus is more effective in treating hypertonic upper limb McCollough NC *et al* (1978). Some studies have reported that two types of splint- dorsal resting hand splint and volar resting hand splint - are effective in spasticity reduction, and most commonly used clinically McPherson JJ (1952), Rose V *et al* (1987).

The effects of resting hand splint can be explained two theories – biomechanical and neurophysiological theories Burge E (2008), Lannin NA *et al* (2003). The biomechanical theory is based on the effect of the extensive changes of muscle and connective tissues caused by mechanical force, and the neurophysiological theory is about the effect of spasticity reduction through the inhibition of reflex muscle contraction Gossman MR (1982), Langlois S *et al* (1987). Applying dorsal resting and splint and volar resting hand splint by a neurophysiological mechanism has been discussed. Some clinicians argue that dorsal resting and splint is more effective because it is supposed that spasticity increases due to the stimulation of hand flexor muscles by volar resting hand splint Lannin NA (2003), Langlois S *et al* (1989). However, from another perspective, both dorsal resting and splint and volar resting hand splint require the contact to the skin surface of the dorsal of the hand and volar. Also, there is a study having reported that hand flexor muscle contraction reflex can be induced by skin stimulation due to the forearmto fix dorsal resting and splint and the finger fixing strap Shah S *et al* (2007).

Like this, in order to evaluate the therapeutic effect according to the types of resting hand splints, particularly the effect of the application of resting hand splint, more strict design is necessary. The effect can vary depending on the degree of a patient's recovery from stroke or application time & period Neuhaus B *et al* (1981) and the characteristics of upper limbs Kuipers K *et al* (2012). From this perspective, it is necessary to compare the effects of each type of resting hand splint including patients' characteristics, which have not been considered in previous studies.

Literature Review

The prognosis of upper limb functional recovery in stroke patients is generally poor McCollough NC *et al* (1978), and upper limb function is not proper in greater than 50% Broeks JG *et al* (1999). Therefore, the maintenance and prevention of joint ROMis essential for ADLs, particularly putting on clothes. Contracture of stroke patients generally occurs in wrists or ankles Pandyan AD *et al* (2003), and because functional activities decrease due to spasticity increase, pain induction, and limited motion resulted from wrist contracture McCollough NC *et al* (1978), postural alignment of joints, joint ROM exercise, and applying resting hand splint are essential for the prevention of contracture Lannin N A (2007). Although the effect of resting hand splint was based on the biomechanical approach until 1950, it is based on the neurophysiological approach to increase the recognition of proprioception by focusing on maintaining right joint posture and muscle extension for the reduction of hypertonicity as well as promotion of normal motion since the cause(s) of spasticity has been identified after 1950's Neuhaus B *et al* (1981). Therefore, this study was designed to investigate the effect of the application of resting hand splint tostroke hemiparesis patients on spasticity and hand functions through the evaluations such as MAS, wrist AROM, and wrist sEMG.

In a previous study, the positive effect of spasticity reduction by applying resting hand – dorsal and volar-splints in stroke patients was not observed, and there was methodological limitation because the sample size was small as 10 subjects McPherson JJ *et al* (1982). According to the study about the significance of the period of resting hand splint application, the effect of resting hand splint on spasticity reduction in stroke patients was partially significant as of the 8th week Pizzi A *et al* (2005). In other studies, the positive effect of spasticity reduction was not obtained as two types of resting hand splint were applied for 4 weeks Lannin *et al* (2007), and a 4-week intervention period was insufficient for muscle extension and more time to reduce resistance was necessary Basaran A *et al* (2012).

In the result of wrist MAS in this study, significant reduction was shown in the group of dorsal restinghand splint. A randomized controlled trial was performed in a total of 52 subjects, and it was supposed that the number of subjects to ensure the effect size as well as the application for 6~8hours daily for 8 weeks had influence. Also, the wrist extension angle of splint, that is, the extension load of hand flexor muscles affects spasticity Shah S *et al* (2007). The effect of spasticity reduction was obtained by applying the resting hand splint with low-load extension intensity, which was manufactured according to the structure and characteristics of a subject's hand Pizzi A *et al* (2005). In this study also, spasticity reduction was obtained by applying the comfortable splint that was manufactured according to low-load extension and characteristics based on the degree of subjects' spasticity. However, there was no significant difference in the group with volar resting hand splint. As volar resting hand splint is mostly in contact with the skin surface of volar, there may be association with previous study results that spasticity can increase even more because of the stimulation of the extension reflex receptor of hand flexor muscles Langlois S *et al* (1989), and the clinical purpose to stabilize hypotonic upper limbs is greater McCollough NC *et al* (1978).

The results of wrist AROM and sEMG in this study proved significant effects in the group of dorsal restinghand splint. In the group of volar resting hand splint, wrist AROM did not show significant increase but there was significant activation of extensor muscle in wrist sEMG. It has been discussed that the measuring equipment for the effect of hand splint application in stroke patients needs to be determined by scientific and electrophysiological equipment rather than clinical findings or common ideas Gracies JM *et al* (2000). Supposedly it was because that the reliability of study results increased by measuring using the surface EMG with high reliability (DataLOG MWX8) and electrogoniometer in this study.

Resting hand splint is provided for the re-education of hand and upper limb functions Pitts DG *et al* (2008). Also, joint deformity is prevented, and extrinsic and intrinsic hand muscles as well as extensor and flexor muscles can be changed through the length-tension relationship of muscle. It has been reported that the splint manufactured according to the characteristics of a patient's upper limb increases the stimulation of sensory-motor system, and can result in the maximum functional recovery through ROM increase and by maintaining function muscle length for gross motor and fine motor. In this study also, wrist AROM increased by spasticity reduction and changes of wrist muscle length in the group of dorsal resting hand splint, and increased joint ROM was supposed to have positive effects on improvement of hand functions.

The ability to maintain function wrist extension (about 10°~30°) by the activities of wrist extensor muscles is essential in the production of great grip strength and hand dexterity Katz R *et al* (1989). Based on the result of this study, the wrist extension angle of resting hand splint was about 10°~30°, and wrist AROM and the activation of extensor carpi radialis, which affect various functional hand activities, were measured.

The limitations in hand stretching, grabbing, and releasing generally occur due to the problem of extension function of hands and wrists after stroke Fayez ES *et al* (2013). This is manifested not only by the weakness of finger extensor muscles but also the stiffness and spasticity of flexor muscles of wrist or fingers. Also, limited grabbing is manifested asthe weakness of finger flexor muscles as well as extensor carpi radialislongus and extensor carpi ulnaris Ruth Turk *et al* (2008). In the re-interpretation of this study result, motion is created by the interaction of agonistic muscle and antagonistic muscle, and because the stiffness and spasticity of wrist or finger flexor muscles work as an inhibitory factor of wrist active extension, reducing this inhibitory factor would have positive influence on wrist active extension. Also, it was discussed about the significant role of wrist extensor muscles in the functional activities of hands. This supports the results of this study and is expected to affect the improvement of hand functions for ADLs such as stretching, grabbing and releasing objects in the future by showing significant improvement in both groups for the activation changes of wrist extensor carpi radialis. However, there was no significant improvement in wrist AROM in the group of volar resting hand splint, indicating that there was no sufficient change of muscle activation to change joint ROM and it was probably affected by the spasticity of wrist flexor muscles.

Based on the result of this study, applying various types of resting hand splints would have positive influence in the improvement of hand functions. Resting hand splint is applied to joint ROM improvement, changes of motion quality, and functional improvement of upper limbs and hands Wilton JC *et al* (1997), and would have great effects in restoring social role(s) by helping the enhancement of ADLs

Fess EE *et al* (2005). Applying resting hand splint to stroke patients would not only have preventive effects but also have great influence on the improvement of hand functions and consequently a greater goal of rehabilitation therapy, social return, in the future.

For the limitations of this study, it is challenging to generalize the study results because the number of previous studies about resting hand splint is insufficient. Also, supposedly the therapeutic effects were mixed because of the influence of early spontaneous recovery of brain damage as patients who developed stroke within 6 months were study subjects and the combination of traditional rehabilitation therapy. Also, the short study period of 8 weeks probably affected the study results. Further studies about more various splints to complement these limitations would bring valuable results.

Proposed Work

Study subjects

This study was performed in two groups, which were determined by random assignment according to the order of visits of 52 subjects who were diagnosed of stroke and disease period was 2-6 months among patients who visited K University Hospital located in Dongdaemun Gu, Seoul from February to April, 2015. Prior to beginning the study, voluntary subjects were recruited and provided with explanation of study purpose and contents, and a written consent form was obtained from the subjects who had strong desire to participate in the study. The sample size was calculated using G-Power program 3.1 Faul F *et al* (2009) for the t-test of two groups at the significance level 0.05, statistical power 0.8, and the effect size 0.8, resulting in a total of 52 for each group of 26 subjects. Cohen d defined the effect size; 0.2 was small, 0.5 was medium, and 0.8 was large. The inclusion and exclusion criteria were based on the previous study of Copley J *et al*. All experimental procedures were approved by the institutional review board (KHUHMDIRB 1501-01).

The Inclusion Criteria are as Follows:

First, adults over 19 years of age

Second, stroke (cerebral hemorrhage and cerebral infarction) patients who disease period was 2-6 months

Third, patients who can communicate and whose mini mental state exam-korean (MMSE-K) is ≥ 24

Fourth, people whose wrist modified ashworth scales (MAS): 1–2 grade

Fifth, people whose wrist manual muscle test (MMT): Trace-Fair grade

Sixth, people who have voluntarily consented to the purpose and methods of this study

The Exclusion Criteria are as Follows:

First, people with the contracture of muscle and soft tissue underneath the arm on the paralyzed side

Second, people with peripheral neuronal damage on the paralyzed side of upper limb and dermatological lesions

Third, people with severe pain on the paralyzed side of upper limb (visual analog scale ≥5)

Fourth, people taking antipasti medications

Fifth, people with cognitive and behavioral disabilities

The study design is shown in Figure 1.

Interventions

Types of Resting Hand Splints

The resting hand splints used in this study were two types – dorsaland volar - of splints. Two resting hand splints were manufactured based on the criteria suggested by Basaranet (2012) and Shah *et al* (2007).

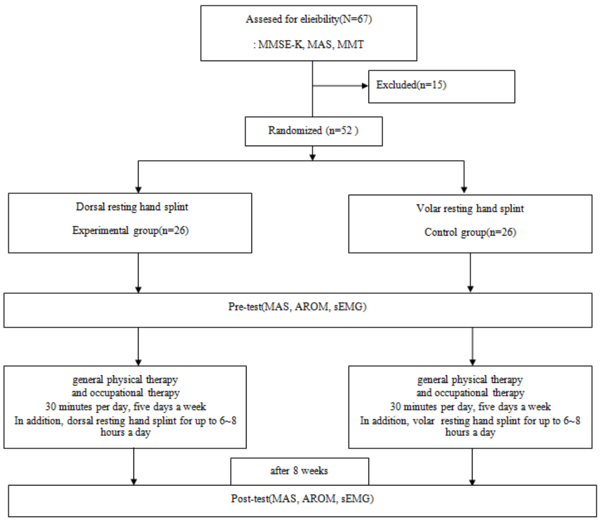

Figure 1. Trial profile

Splints were manufactured by an occupational therapist with more than 10 years of clinical experiences, and 3.2mm×45cm×60cm of Orthoplast material (ORFIT manufacturer) was used. Once paper was drafted according to the shape and size of a subject's upper limb, the original design was drawn on the material and cut. Then, hot water (about 70°c) was added to increase plasticity and a personalized splint was manufactured. The wrist extension angle of resting hand splint was 10°-30° of wrist extension, the functional posture of a hand Lannin NA *et al* (2003) ,and was determined slightly differently according to the spasticity of each subject. Because hyperextension of muscle can increase further spasticity by inducing extension reflex, it should be determined within the previous passive ROM, in which the maximum resistance of maximum muscle extension is felt Shah S *et al* (2007). Thus, about 10° reduced angle from the maximum resistance angle of muscle extension was applied Basaran A *et al* (2012).

The application time of resting hand splint was 6~8 hours per day Pandyan AD *et al* (2003), and the intervention period was 8 weeks Lannin NA *et al* (2003) based on the positive effect of a previous study. The application of resting hand splint lasted for 2 hours with a resting time and was repeated in reference of daytime/night in order to minimize the risk of muscle or skin damage, and subjects as well as their caregivers were educated about a proper method to apply. They were instructed to comply strictly with splint application through the daily checklist of splint application.

Conventional Rehabilitation Therapy

All study participants received occupational and physical therapies for 30 minutes daily 5 times a week. Occupational therapy is a therapy to restore physical functions to improve ADLs, and trainings of ADLs and upper limb muscles were performed using a variety of selected tools. For physical therapy, gait exercise, posture control training, joint ROM exercise, and muscle strengthening exercise were performed.

Evaluation and Evaluation Tools

Spasticity Test

(A) Modified Ashworth Scales (MAS)

Modified Ashworth Scale (MAS) was developed by Ashworth, and revised to 6 grades by Bohannon *et al*. 0: there is no muscle intensity or resistance increase. 1: A little resistance felt at the end of joint ROM by passive flexion of affected upper limb or extension. 1+: Resistance felt from ½ below the entire joint ROM. 2: Resistance felt in most joint ROM but movable. 3: Resistance felt to make passive movement challenging. 4: Infeasible movement within the joint ROM of flexion and extension. The test was performed while a subject was in supine position without moving upper limb, and the wrist joint was rapidly passively extended at completely flexed position by the force of the examiner. The degree of resistance that an examiner subjectively felt was graded Sloan RL (1992). This was repeated 4 times and the mean was used. Test-retest reliability was r=.83, and inter-rater reliability was high as r=.84 Gregson JM *et al* (1999).

Hand Function Test

(A) Wrist sEMG Test

In this study, the surface EMG machine, Data LOG MWX8(Biometrics Inc, UK) was used. ROM of the entire body including upper and lower limbs can be continuously measured and analyzed digitally. In order to measure wrist sEMG, surface EMG signal sampling rate was 1,000Hz, and for filter the sampling rate was 20Hz~450Hz per a channel Motamedzade M *et al* (2014). For measurement, a subject was in a stable sitting position with upper limb on the table in front of him/her, and EMG sensor (SX230-1000) was attached to the skin of extensor carpi redialis (ECR) using double-sided tape after alcohol disinfection. Maximum active extension lasted for 5 seconds, followed by resting for 2 minutes, and this was repeated 3 times. Then, the mean of the values for 3 seconds excluding the first and last 1 second during 5 seconds was obtained You SJ *et al* (2013). Root mean square (RMS) was yielded.

(B) Wrist Active Range of Motion (AROM)

In this study, wrist AROM was evaluated using electrogoniometer. Using a two-dimensional electronic protractor (SG type, Biometrics Inc., DataLog, UK), medical double-sided tape was attached to the skin of bilateral wrist joints, the inner side of 1/3 radial forearm, and dorsal side of the middle phalanx of the middle finger. The wrist angle in a sitting position with pronated hands on the towel on a table in front of a subject was defined as 0. By the examiner's instruction for the maximum wrist extension for 3 seconds, the maximum wrist extension joint ROM was used for the wrist AROM of subjects, and the frequency of sampling was 50 per a second.

Analytic Methods

The data collected in this study was analyzed using SPSS version 18.0. In order to analyze the general characteristics of participants,frequency analysis of descriptive statistics and Chi-Square test were used, and normality test was performed. For the homogeneity test prior to intervention in two groups, independent sample*t*-test was performed. For the difference in MAS, sEMG, and AROMbefore and after the interventionin two groups, paired *t*-test was performed, and independent sample*t*-test was performed to compare the change(s) before and after the intervention in two groups. Statistical significance level was α=.05.

Results

The general characteristics of the participants are described below. (Table 1)

Wrist MAS, wrist AROM, and Change(s) before and after the Intervention of Wrist sEMG in the Experimental Group (Table 2)

The wrist MAS, wrist AROM, and the change of wrist sEMG in the experimental group are shown in table 3. The MAS was grade 1.35±.629 in pre-test and grade .88±.711 in post-test (p<.01). The AROM was8.73±8.879° in pre-test and 12.96±12.901° in post-test (p<.05).

Table 1. Characteristics of participants

Characteristics	Experimental Group (n=26)	Control group (n=26)
Age(year), mean±SD	65.77±10.11	61.62±10.05
Gender (male/ female)	14/12	16/16
Type of stroke (Hemorrhage/ Infarction)	7/19	8/18
Side of stroke (Right/Left)	11/15	9/17
Time since onset of stroke months, mean ± SD	3.38±1.49	3.54±1.42

SD: standard deviation.

Table 2. Comparison of results between Experimental group and control group

	Experimental group			Control Group		
	Before treatment	After treatment	Mean difference	Before treatment	After treatment	Mean Difference
MAS (grade)	1.35 (0.629)	0.88 (0.711)*	-0.54 (0.647)†	1.38 (0.637)	1.19 (0.749)	-0.15 (0.543)
AROM (angle)	8.73 (8.879)	12.96 (12.901)*	4.23 (7.906)†	12.08 (13.199)	12.85 (13.199)	0.77 (2.388)
sEMG (mv)	0.028 (0.024)	0.037 (0.033)*	0.009 (0.015)	0.038 (0.039)	0.042 (0.041)*	0.003 (0.009)

The values are mean ± standard deviation,MAS:Modified AshworthScale,
AROM :Active Range Of Motion, sEMG: surface ElectroMyoGraphy
*p<0.05 by Paired *t* test, †p<0.05 by Independent *t* test.

The sEMG was .028±.024mv in pre-test and .037±.033mvin post-test (p<.01), and there were significant improvements in all three tests as a result of analyzing before and after the intervention.

Wrist MAS, Wrist AROM, and Change(s) before and after the Intervention of Wrist sEMG in the Control Group (Table 2)

The wrist MAS, wrist AROM, and the change of wrist sEMG in the control group are shown in table 4. The MAS was grade 1.38±.637 in pre-test and grade 1.19±.749 in post-test (p>.05). The AROM was 12.08±13.199° in pre-test and 12.85±13.199° in post-test (p>.05).

The sEMG was .038±.039mv in pre-test and .042±.041mv in post-test (p<.05). There was no significant difference in MAS and AROM as a result of analyzing before and after the intervention. However, sEMG showed a significant difference.

Comparison of the Changes of Wrist MAS, AROM, and sEMG between the Experimental and Control Groups (Table 2)

The comparison of the changes of wrist MAS, AROM, and sEMG between the experimental and control groups is presented in table 5. The change of MAS was -.54±.647 in the experimental group, and -.15±.543 in the control group, showing a statistically significant difference (p<.05).

The change of AROM was 4.23±7.906° in the experimental group, and .77±2.388° in the control group, showing a statistically significant difference (p<.05).There was no significant difference in sEMG(p>.05).

Conclusion

This study was designed to investigate the effects of various resting hand splints for 8 weeks in stroke hemiparesis patients on the spasticity and hand function through wrist MAS, AROM, and sEMG. The study results are as follows.

First, there was a significant difference in wrist MAS, AROM, and sEMGin the group of dorsal restinghand splint.

Second, there was no significant difference in wrist MAS and AROM in the group of volar resting hand splint, but there was a significant difference in wrist sEMG.

Third, there was a significant difference in wrist MAS and AROM in the group ofdorsal restinghand splint as a result of comparing change(s) between two groups, but there was no significant difference in wrist sEMG. Through this study, it was found that dorsal restinghand splint was more effective in the reduction of wrist spasticity and improving AROM than volar resting hand splint in stroke patients. Also, as there was a significant difference in wrist sEMG in both groups, it is expected that extensor muscle activation would increase hand function. Therefore, it is supposed to be an effective treatment for the hand function improvement of stroke patients. Finally, this would be able to contribute to the policy to reduce social burden by reducing medical fee of stroke patients.

References

Kogler G.F., Gelber D.A. and Jeffery D.R., (2002) Current Clinical Neurology: Clinical Evaluation and Management of Spasticity. Totowa, *NJ: Humana Press*. 67-91.

Dietz, V. and Sinkjaer, T. (2007) Spastic Movement Disorder: Impaired Reflex Function and Altered Muscle Mechanics, *Lancet Neurology* **6**, 725-733.

Foran, J. R., Steinman, S., Barash, I., Chambers, H. G. and Lieber, R. L. (2005) Structural and Mechanical Alterations in Spastic Skeletal Muscle. *DevMed Child Neurol*. **47**, 713–717.

O'Dwyer, N. J., Ada, L. and Neilson, P. D. (1996) Spasticity and Muscle Contracture following Stroke. *Brain* **119,** 1737-1749.

R. Boyd, M. Morris and H. Graham. (2001) Management of Upper Limb Dysfunction in Children with Cerebral Palsy: A Systematic Review**.** *European Journal of Neurology*. **8,** 150-166.

Robinson R.G., Starr L.B., Kubos K.L. and Price T.R. (1983) A Two-Year Longitudinal Study of Post-Stroke Mood Disorders: Fi Ndings During the Initial Evaluation. *Stroke*. **14**, 736-741.

Pizzi A., Carlucci G., Falsini C., Verdesca S. and Grippo A. (2005) Evaluation of Upper-Limb Spasticity After Stroke: A Clinical and Neurophysiologic Study. *Arch Phys Med Rehabil*. **86**, 410–415.

Burge E., Kupper D., Finckh A., Ryerson S., Schnider A. and Leemann B. (2008) Neutral Functional Realignment Orthosis Prevents Hand Pain in Patients with Subacute Stroke: A Randomized Trial. *Arch Phys Med Rehabil.* **89**, 1857–1862.

Delcourt C., Hackett M. and Wu Y., *et al*. Determinants of Quality of Life after Stroke in China: The China QUEST (Quality Evaluation of Stroke Care and Treatment) Study [published online ahead of print December 23, 2010]. *Stroke*.

Elovic E., DeLisa J.A., Gans B.M. and Walsh N.E., (2005) Physical Medicine and Rehabilitation: Principles and Practice. 4th ed. Philadelphia: *Lippincott Williams & Wilkins*. **11**, 1427–1446.

Williams Pedretti L., Smith J.A. and McHugh Pendleton H. (1996) Cerebral vascular Accident. In: Williams PedrettiL ed. Occupational Therapy Practice Skills for Physical Dysfunction, fourth edition. St Louis: *Mosby*. 785–805.

Milazzo S. and Gillen G. Splinting Applications. In: Gillen G., Burkhardt A. eds. (1998) Stroke Rehabilitation: A fFunction-Based Approach. St Louis: *Mosby*. 161–184.

Wilton J.C. Splinting and Casting in the Presence of Neurological Dysfunction. In: JC.Wilton ed. (1997) Hand Splinting: Principles of Design and Fabrication. London: *WB Saunders.* 168–97.

Edwards S. and Charlton P.T. Splinting and use of Orthoses in the Management of Patients with Neurological Dysfunction. In: Edwards S. Ed. (1996) Neurological Physiotherapy: A Problem Solving Approach. London: *Churchill Livingstone*. 161.

McPherson J.J., Kreimeyer D., Aalderks M. and Gallagher T. (1982) A Comparison of Dorsal and Volar Resting Hand Splints in the Reduction of Hypertonus. *Am J OccupTher.* **36**, 664–670.

Gracies, J. M. (2005) Pathophysiology of Spastic Paresis. II: Emergence of Muscle Overactivity. *Muscle & Nerve* **31**, 552-571.

Kottke, F. J., Pauley, D. L. and Ptak, R. A. (1996) The Rationale for Prolonged Stretching for Correction of Shortening of Connective Tissue. *Arch Phys Med Rehabil.* **47**, 345-352.

Sheehan, J. L., Winzeler-Mercay, U., and Mudie, M. H. (2006) A Randomized Controlled Pilot Study to Obtain the Best Estimate of the Size of the Effect of a Thermoplastic Resting Splint on Spasticity in the Stroke-Affected Wrist and Fingers*. ClinRehabil.* **20**, 1032-1037.

Lannin, N. A., Cusick, A., McCluskey, A., and Herbert, R. (2007) Effects of Splinting on Wrist Contracture after Stroke*. Stroke*. **38**, 111-116.

Lannin, N. A., Horsley, S. A., Herbert, R., McCluskey, A., and Cusick, A. (2003) Splinting the Hand in the Functional Position after Brain Impairment: A Randomized, Controlled Trial. *Arch Phys Med Rehabil*. **84,** 297-302.

Pitts D.G. and O'Brien S.P. (2008) Splinting the Hand to Enhance Motor Control and Brain Plasticity. *Top Stroke Rehabil.* **15**, 456–467.

Lannin N.A. and Herbert R.D. (2003) Is Hand Splinting Effective for Adults Following Stroke? A Systematic Review and Methodologic Critique of Published Research. *ClinRehabil*. **17**, 807–816.

McCollough N.C., (1978) 3rd. Orthotic Management in Adult Hemiplegia. *ClinOrthopRelat Res*. 3846.

Rose V. and Shah S. (1987) A Comparative Study on the Immediate Effects of Hand Orthoses on Reduction of Hypertonus. *AustOccupTher J*. **34**, 59–64.

Lannin N.A., Horsley S.A., Herbert R., McCluskey A. and Cusick A. (2003) Splinting the Hand in the Functional Position after Brain Impairment: A Randomized, Controlled Trial. *Arch Phys Med Rehabil*. **84**, 297–302.

Gossman M.R., Sahrmann S.A. and Rose S.J. (1982) Review of Length-Associated Changes in Muscle. Experimental Evidence and Clinical Implications. *PhysTher*. **62**, 1799–1808.

Langlois S., MacKinnon J.R. and Pederson L. (1989) Hand Splints and Cerebral Spasticity: A Review of Literature. *Can J OccupTher.* **56**, 113–119.

Shah S. (2007) Wrist Splint for Upper Motor Neuron Paralysis. *Stroke*. **38**, e75.

Neuhaus B., Ascher V. and Coullon B., *et al*. (1981) A Survey of Rationales for and Against Hand Splinting in Hemiplegia. *Am J OccupTher*. **35**, 83-9.

Kuipers, K., Burger, L. and Copley, J. (2012) Casting for Upper Limb Hypertonia: A Retrospective Study to Determine the Factors Associated with Intervention Decisions. *Neurorehabil*. **31**, 409-420.

Broeks J.G., Lankhorst G.J., Rumping K. and Prevo A.J. (1999) The Long-Term Outcome of Arm Function after Stroke: Results of a Follow-Up Study. *DisabilRehabil*, **21**, 357–364

Pandyan A.D., Cameron M., Powell J., Stott D.J. and Granat M.H. (2003) Contractures in the Post-Stroke Wrist: A Pilot Study of its Time Course of Development and its Association with Upper Limb Recovery. *ClinRehabil.* **17**, 88–95.

Basaran, A., Emre, U., IkbalKaradavut, K., Balbaloglu, O., and Bulmus, N. (2012) Hand Splinting for Poststroke Spasticity: A Randomized Controlled Trial. *Topics in stroke rehabilitation*. **19**, 329-337.

Gracies J.M., Marosszeky J.E., Renton R., Sandanam J., Gandevia S.C. and Burke D. (2000) Short-Term Effects of Dynamic Lycra Splints on Upper Limb in Hemiplegic Patients. *Arch Phys Med Rehabil*. **81**, 1547–1555.

Katz R. and Rymer W.Z. (1989) Spastic Hypertonia: Mechanism and Measurement. *Arch Phys Med Rehabil.* **70**, 144-55.

Fayez, E. S., and Sayed, H. M. (2013) Influence of Different Types of Hand Splints on Flexor Spasticity in Stroke Patients. *Indian Journal of Physiotherapy and Occupational Therapy*. **7**, 65

Ruth Turk, Jane H. Burridge and Ross Davis. (2008) Therapeutic Effectiveness of Electric Stimulation of the Upper-Limb Poststroke using Implanted Microstimulators. *Arch Phys Med Rehabil.* **89**, 1913-1922

Fess E.E., Gettle G.S., Philips C.A. and Janson J.R. (2005) Hand and Upper Extremity Splinting: Principles and Methods. St. Louis: *Elsevier/Mosby*;

Faul, F., Erdfelder, E., Buchner, A., and Lang, A.G. (2009) Statistical Power Analyses using G*Power 3.1: Tests for Correlation and Regression Analyses. *Behavior Research Methods*. **41**, 1149-1160.

Copley, J., Kuipers, K., Fleming, J., and Rassafiani, M. (2013) Individualised Resting Hand Splints for Adults with Acquired Brain Injury: A Randomized, Single Blinded, Single Case Design. *Neurorehabil*. 3**2**, 885-898.

Bohannon R.W. and Smith M.B. (1987) Interrater Reliability on a Modified Ashworth Scale of Muscle Spasticity. *PhysTher.* **67**, 206-207.

Sloan, R. L., Sinclair, E., Thompson, J., Taylor, S., and Pentland, B. (1992) Inter-Rater Reliability of the Modified Ashworth Scale for Spasticity in Hemiplegic Patients. *International Journal of Rehabilitation Rresearch*. **15**, 158-161.

Gregson, J. M., Leathley, M., Moore, A. P., Sharma, A. K., Smith, T. L., and Watkins, C. L. (1999) Reliability of the Tone Assessment Scale and the Modified Ashworth Scale as Clinical Tools for Assessing Poststroke Spasticity. *Archives of physical medicine and rehabilitation*. **80**, 1013-1016.

Motamedzade, M., Afshari, D., and Soltanian, A. (2014) The Impact o Ergonomically Designed Workstations on Shoulder EMG Activity During Carpet Weaving. *Health promotion perspectives*. **4**, 144.

You, S. J., and Lee, J. H. (2013) Effects of Mental Activity Training Linked with Electromyogram-Triggered Electrical Stimulation on Paretic Upper Extremity Motor Function in Chronic Stroke Patients: A Pilot Trial. *Turkish Journal of Physical Medicine & Rehabilitation/TurkiyeFiziksel Tip veRehabilitasyonDergisi*. 59.