NeuroRehabilitation 28 (2011) 55–61
DOI 10.3233/NRE-2011-0632
IOS Press



# New design of dynamic orthoses for neurological conditions

Henry B. Hoffman[a,*] and Glyn L. Blakey[b]
[a]*Saebo Inc, Charlotte, NC, USA*
[b]*Saebo UK Limited, Welwyn Garden City, Hertfordshire, UK*

**Abstract**. Repetitive task-specific training appears to improve upper extremity function among individuals with neurological injuries. However, treatment options are limited for neurological patients who cannot effectively incorporate their hand consistently for functional grasp and release/prehension activities. Traditional therapy approaches are not considered to be effective in controlled clinical trials. However, constraint induced movement therapy (CIMT) has shown to be a successful treatment approach for patients who exhibit some wrist and finger extension. The vast majority of stroke survivors, head injury and incomplete spinal cord Injury patients do not exhibit sufficient wrist and/or finger extension to qualify for CIMT. Patients with moderate to severe upper extremity hemiparesis are therefore unable to benefit from the latest advances in neuro-rehabilitation. The SaeboFlex and SaeboReach Functional Dynamic Orthoses have the biomechanical advantage in allowing prehension / grasp and release activities for individuals with moderate to severe hemiparesis. These orthoses are designed to position the neurological wrist and fingers into extension for proper functional training. This article describes Saebo's functional dynamic orthoses - the SaeboFlex, SaeboReach, and the SaeboStretch dynamic resting hand splint for contracture prevention - and summarizes developing evidence for the orthoses in the clinic/rehabilitation environment. This is a review article.

Keywords: Stroke, brain injury, functional orthoses, rehabilitation, arm, hand

## 1. Introduction

Patients who demonstrate moderate to severe upper extremity hemiparesis are unable to functionally engage their upper limb. Consequently, learned nonuse is thought to further decrease movement and increase pain [23]. The inability to effectively incorporate the paretic limb into tasks can lead to decreased cortical activation [12,16] and longer term functional limitations.

For the purpose of this article, moderate to severe upper extremity (UE) hemiparesis is defined as relating to neurological patients who lack wrist and finger extension of their involved side and may also exhibit hypertonicity. Traditional therapy approaches such as passive range of motion, manual handling, weight-bearing and tone-reduction strategies to address moderate to severe UE hemiparesis have not been shown efficacious with respect to distal recovery [20]. Task-specific strategies with repetition are recommended within the literature, including neurorehabilitative modalities such as electrical stimulation. In recent years, there have been several clinical trials demonstrating that repetitive task-specific training improves upper extremity function in individuals suffering from neurological injuries [2,18,25–27]. Additionally, repeatedly incorporating the involved neurological limb with task-specific motor activities has also shown long term cortical reorganization [6,15].

One particular treatment approach that has received much attention in recent years is constraint induced movement therapy (CIMT) which involves restraining the less-impaired upper extremity while performing intense task specific training of the paretic side. Research indicates that CIMT is an effective treatment option for hemiparetic patients that exhibit some wrist and finger extension [28]. Although the recent advances in neu-

*Corresponding author: Henry Hoffman, Saebo, Inc., 2725 Water Ridge Pkwy, Ste 320, Charlotte, NC 28217, USA. Tel.: +1 888 284 5433; Fax: +1 704 424 2911; E-mail: hhoffman@saebo.com.

ISSN 1053-8135/11/$27.50 

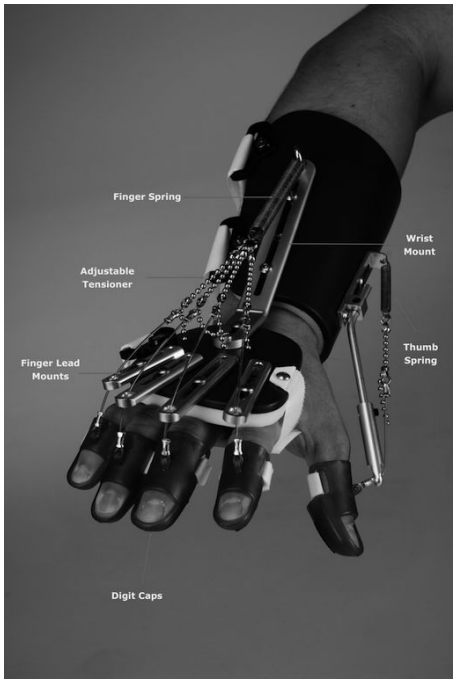



Fig. 1. SaeboFlex Orthosis.

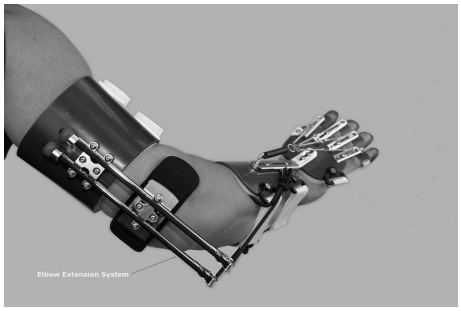



Fig. 2. SaeboReach Orthosis.

rorehabilitation treatment are effective for the mild to moderate impaired neurological hand and arm, individuals suffering from moderate to severe upper extremity hemiparesis are unable to benefit from similar treatment principles since inclusion criteria involves the ability to extend the wrist and fingers. Functional activities involving the impaired hand (i.e., grasp and release) are typically not possible for this population due to their inability to effectively engage the involved upper limb in "daily living" tasks.

The use of neurorehabilitation orthoses has gained recent popularity to overcome this training barrier. Saebo's Functional Neurological Dynamic Orthoses the SaeboFlex and SaeboReach (see Figs 1 and 2), are devices that are used to treat patients with limited or no hand and arm function. These orthoses, being a distal medium, allow patients with moderate to severe UE hemiparesis to participate in the latest treatment advances by incorporating their affected hand repeatedly for task-specific training. Through the use of the orthosis, repetitive task-specific training can be offered, challenging traditional neurorehabilitative concepts, including a paradigm shift from "proximal to distal" [20] recovery to "distal to proximal" recovery (see Fig. 3a and 3b).

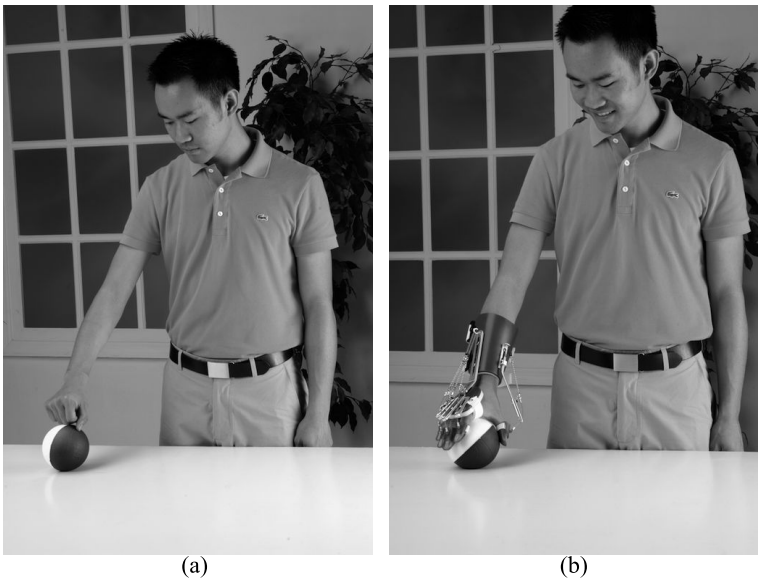
The following sections discuss the potential benefits and features of the SaeboFlex, SaeboReach, and SaeboStretch.

## 2. SaeboFlex

The SaeboFlex is a dynamic custom-fabricated wrist, hand, finger orthosis (WHFO). The forearm shell and hand piece are fabricated to a specific patient's clinically derived measurements and the orthosis includes a dynamic finger and thumb extension assist. The extension system is comprised of resistive springs of varied force. For instance, if the goal is to increase grip strength, then a more resistive spring is used. Conversely, if the goal is to improve volitional deactivation of the flexors and strengthen the finger extensors, then a less resistive spring may be used. Moreover, if the patient exhibits a weak grasp, then a less resistive spring is selected. However, if the patient is able to grasp the object, but is having difficulty with release, then a more resistive spring is chosen. During the adjustments phase, the therapist determines which resistive spring to select for the fingers and thumb based on the amount of weakness, selective control and spasticity the patient exhibits.

After selecting the appropriate finger and thumb springs, they are then connected to an adjustable tensioner. Therefore, although one spring is responsible for all four digits, the adjustable tensioner allows clinicians to further customize the amount of tension needed for proper grasp and release.

Four Finger Lead Mounts are positioned on the distal portion of the dorsal hand piece. These mounts are similar in function to outriggers on other dynamic orthoses. The Finger Lead Mount serves to provide the appropriate angle of pull; the tensioner passes through the opening of the Finger Lead Mount and inserts onto the individual Digit Caps. The thumb also has a similar mounting system. The tensioner passes through the



(a) (b)

Fig. 3. (a) Without the SaeboFlex; (b): With the SaeboFlex.

opening of the Thumb Line Guide and inserts onto the thumb Digit Cap.

Digit Caps are used to block the DIP joints of the fingers and IP joint of the thumb. For mechanically correct grasp and release to occur in hemiparetic patients with flexor synergy influence, the DIP joints of the fingers and IP joint of the thumb should remain at neutral. If the DIP joint or IP joint is positioned in flexion, then it is difficult for the patient to effectively grasp an object.

The natural or self-selected position of the wrist following maximum grip effort is 35 degrees [17]. Consequently, the optimum wrist angle of the SaeboFlex is positioned at 35 degrees of extension. If the patient has increased tone/spasticity and/or soft tissue shortening, then a 15 degree wrist mount is recommended. Biomechanically, the SaeboFlex positions the wrist and hand in extension in preparation for a prehension task.

Following volitional recruitment of the thumb and finger flexors (grasping), the patient sufficiently relaxes his or her flexors to allow the extension spring system to assist with reopening the fingers.

Research has shown that muscle weakness is a major cause of upper limb dysfunction [1,9]. Several studies have shown that strength training is possible without an increase in muscle tone [4,8,21]. Hemiparetic patients using the SaeboFlex to perform repeated grasp and release movements "contract and relax" have shown a decrease in spasticity rating [7]. Clinical data has shown that muscle activation while the muscle is on stretch can reduce sensitivity of the stretch reflex when the muscle is returned to its normal length [22]. Stable bonds are thought to form between actin and myosin filaments immediately following muscle contraction at a determined length [10], thus "resetting" the muscle spindle.

The primary benefit of the SaeboFlex in this population is the facilitation of massed practice and improvement in motor control and overall arm function. Research in this area is in its infancy, however results look promising. For example, a single-group study of chronic patients with upper limb hemiparesis ($n = 19$) [11] showed significant gains in upper limb function as assessed by the Fugl-Meyer Test, and the Action Research Arm Test, and in grip and pinch force (key grip). Significant improvements were also noted on the "physical domain" scales (strength, hand function, mobility, and ADL) of the Stroke Impact Scale.

## 3. SaeboReach

Building on the SaeboFlex, the SaeboReach is a dynamic custom fabricated elbow, wrist, hand, finger orthosis (EWHFO) which includes an elbow component. The proximal component includes an above elbow cuff that supports the dynamic extension system and assists with extending the elbow during functional reaching (see Fig. 2). The distal component of the SaeboReach is the SaeboFlex. During functional reaching activi-

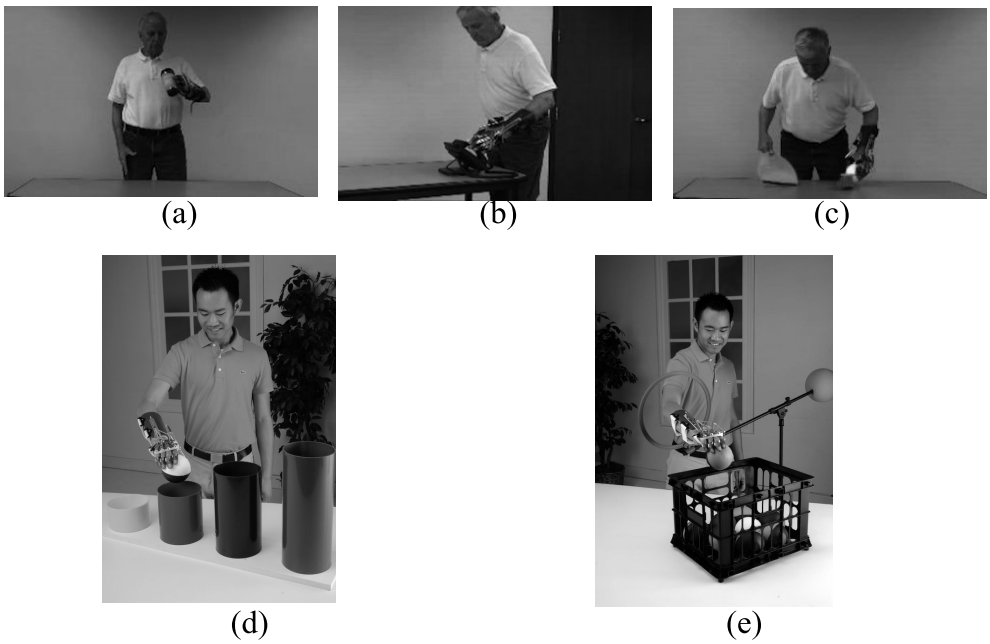



Fig. 4. (a): Grasping a cup; (b): Picking up the phone; (c): Sweeping with a brush; (d): Arm Training Drills using the Four Tier Ball Activity; (e): Arm Training Drills using the Height Adjustable Target.

ties, the user learns to deactivate the elbow flexors and allows the extension system to extend the elbow during task-specific training. The SaeboReach can be adjusted by the therapist to facilitate or inhibit supination and pronation during grasping.

The Saebo orthoses are best applied to patients for task-specific training in therapy and at home. Individual progress has anecdotally varied between patients; some users require the orthosis long-term while others improve hand function to the point where they no longer need the device. The patient and therapist jointly develop a program which will focus on improving motor impairments while simultaneously maximizing upper limb function through the use of the orthosis.

Both the SaeboFlex and SaeboReach have emerged as new and promising treatment alternatives for hemiparetic patients exhibiting moderate to severe UE hemiparesis. Through the use of these dynamic orthoses, patients can functionally incorporate their paretic limb into not only task-specific movement training but also daily activities (see Fig. 4a–e) which can result in improved overall arm function and quality of life [5,7, 11].

## 4. SaeboStretch

Another neuro-orthotic concept that has emerged in recent years is dynamic splinting to address contracture prevention/resolution and hypertonicity. While prospective incidence studies in stroke are lacking, half of all survivors are thought to exhibit contractures following stroke [19]. Many therapists splint their patient's neurological deficits with the goal of preventing/minimizing contracture, increasing soft tissue length, and decreasing tone/spasticity [24]. His-

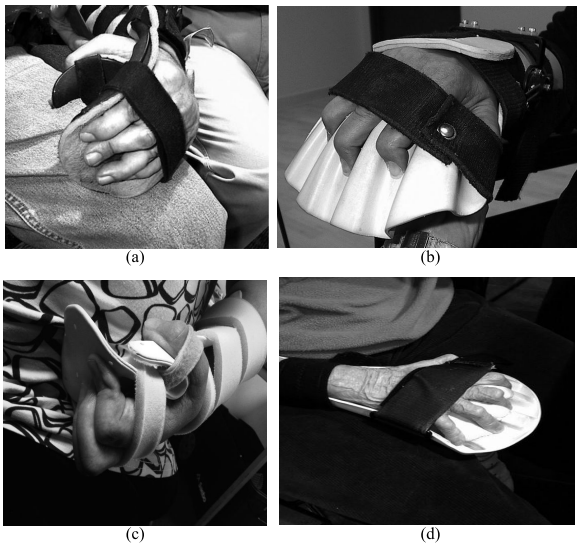



Fig. 5. a, b, c, d: Splinting a spastic hand in a static splint may cause permanent damage and pain at the IP joints.

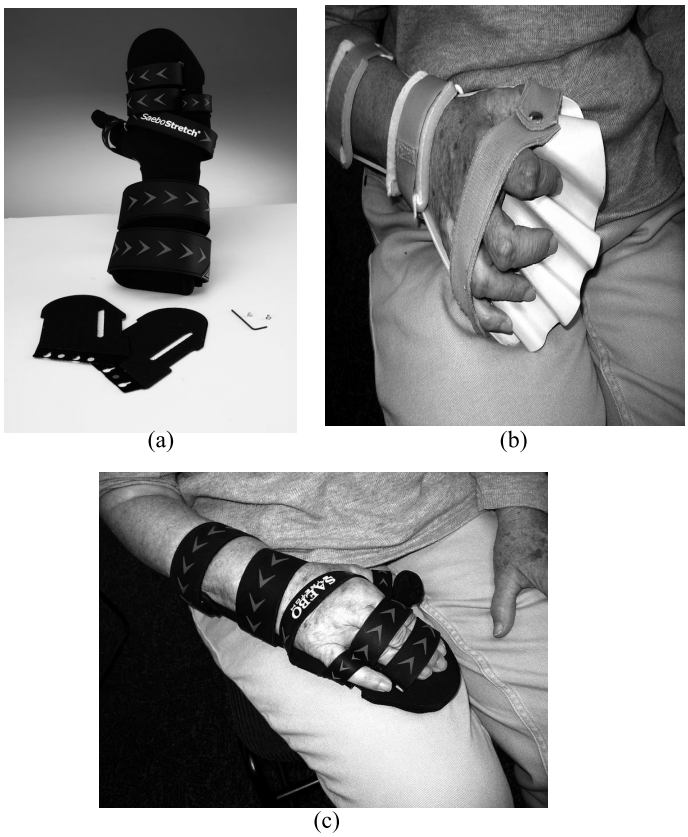



Fig. 6. (a): SaeboStretch Orthosis include 3 dynamic hand plates (energy-storing) with varying degrees of resistance; (b): Stroke patient splinted with traditional static splint; (c): Same stroke patient splinted with the SaeboStretch.

torically, therapists have provided custom fabricated or prefabricated resting hand splints to address these goals, however research has demonstrated that such static splints do not minimize contracture as clinically thought [13,14,24]. The notion of static splinting may also lead to unintended clinical ramifications, potentially increasing stress on the finger and thumb joints (see Fig. 5a–d).

Chronic imbalances of the force about a joint or series of joints can lead to deformities [3]. The SaeboStretch resting hand splint was specifically developed to address the concern of increased stress on the joints and overcome the lack of evidence for static orthoses to address contracture development. The SaeboStretch is a dynamic progressive splint for neurologically involved patients that exhibit hypertonicity (see Fig. 6a–c). The splint assists with protecting the joints while improving and maintaining range of motion. It includes three "energy storing" hand plates that offer various grades of resistance. Therefore, as tone increases in the patient's hand, the fingers flex in the splint instead of pulling out. The dynamic hand piece then repositions the fingers into extension as tone subsides (see Fig. 7a–d). In addition to selecting the appropriate dynamic hand plate, the therapist can pre-position the wrist and thumb angles by bending the malleable metal. The appropriate angle is determined based on the amount of soft tissue shortening and spasticity the patient exhibits. As soft tissue length/tone improves, the angle is adjusted to apply an increased stretch on the flexors. Although not yet evaluated for efficacy within a clinical trial, use of a dynamic orthosis for stretch instead of a static orthosis traditionally used acknowledges the lack of scientific support for static splinting [24].

## 5. Conclusion

Dynamic neurorehabilitation orthoses should be considered when treating patients with upper extremity hemiparesis. Considerable evidence suggests that repetitive, task-specific training improves arm and hand function in neurological patients [25,27]. However,

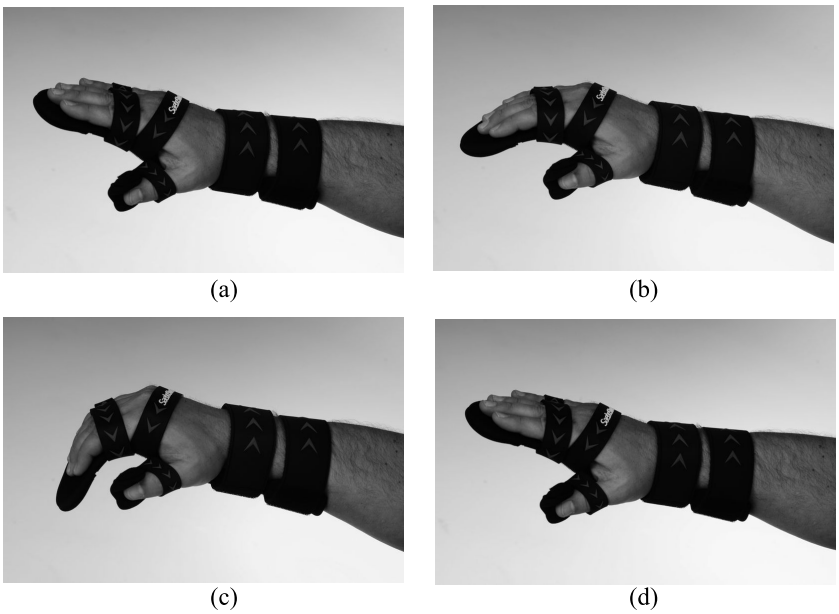



Fig. 7. (a): Patient's hand at rest in the SaeboStretch; (b): Due to associated reactions, the tone increases causing the fingers to flex; (c): As the tone continues to increase, the dynamic hand plate allows the fingers to safely move into flexion; (d): As tone decreases following the associated reaction, the energy-storing hand plate repositions the fingers into extension.

individuals with moderate to severe upper extremity paresis are unable to effectively incorporate their impaired limb into task-oriented training because of limited hand function. If a patient does not qualify for CIMT, then there is little guidance in existing motor training programs for increasing functional activity. Functional dynamic neurorehabilitation orthoses have shown great promise and offer patients an alternative option. Through the use of functional orthoses, patients can engage their involved hand into repetitive, task-specific training which may lead to improvements in upper limb function.

As well as providing a functional orthosis to incorporate the neurological hand, contracture prevention/resolution should also be considered as part of the overall treatment plan. Static rigid splints may cause increase stress on the finger joints which may lead to pain and joint damage in patients who exhibit increased tone. Resting hand splints that offer a flexible, dynamic hand piece may be a better alternative.

## References

[1] L. Ada, N. O'Dwyer and E. O'Neill, Relation between spasticity, weakness and contracture of the elbow flexors and upper limb activity after stroke: An observational study, *Disability and Rehabilitation* (13–14) (2006), 891–897.

[2] S. Barecca, S.L. Wolf, S. Fasoli and R. Bohannon, Treatment interventions for the paretic upper limb of stroke survivors: A critical review, *Neurorehabilitation and Neural Repair* **17**(4) 2003, 220–226.

[3] P. Brand and A. Hollister, *Clinical Mechanics of the Hand*, (3rd edition), C.V. Mosby, 1999.

[4] C. Butefisch, H. Hummelsheim, P. Denzler et al., Repetitive training of isolated movements improves the outcome of motor rehabilitation of centrally paretic hand, *Journal of Neurological Sciences* **130** (1995), 59–68.

[5] A.J. Butler, S. Blanton, V.T. Rowe and S.L. Wolf, Attempting to improve function and quality of life using the FTM protocol: Case report, *Journal of Neurologic Physical Therapy* **30** (2006), 148–156.

[6] J. Classen, J. Liepert, S.P. Wise, M. Hallett et al., Rapid plasticity of human cortical movement representation induced by practice, *Journal of Neurophysiology* **79** (1998), 1117–1123.

[7] J.F. Farrell, H.B. Hoffman, J.L. Snyder, C.A. Giuliani and R.W. Bohannon, Orthotic aided training of the paretic upper limb in chronic stroke: results of a phase 1 trial, *NeuroRehabilitation* **22** (2007), 99–103.

[8] E.G. Fowler, T.W. Ho, A.L. Nwigwe et al., The effect of quadriceps femoris muscle strengthening exercises on spasticity in children with cerebral palsy, *Physical Therapy* **81**(6) (2001), 1215–1123.

[9] C. Gowland, H. deBruin, J.V. Basmajian, N. Plews et al., Agonist and antagonist activity during voluntary upper-limb movement in patients with stroke, *Physical Therapy* **72** (1992), 624–633.

[10] J.E. Gregory, D.L. Morgan and U. Proske, Changes in the size of the stretch reflex of cat and man attributed to after effects in muscle spindles, *Journal of Neurophysiology* **58** (1987), 628–640.

[11] K.F. Heise, G. Liuzzi, M. Zimerman, C. Gerloff and F. Hum-

mel, *Intensive orthosis-based home training of the upper limb leads to pronounced improvements in patients in the chronic stage after brain lesions*, Poster presentation, World Congress of NeuroRehabilitation, Vienna, March 2010.

[12] J.A. Kleim, S. Barbay and R.J. Nudo, Functional reorganization of the rat motor cortex following motor skill learning, *J Neurophysiol* **80**(6) (1998), 3321–3325.

[13] N.A. Lannin, A. Cusick, A. McCluskey and R. Herbert, Effects of splinting on wrist contracture after stroke: A randomized controlled trial, *Stroke* **38** (2007), 111–116.

[14] N.A. Lannin, S. Horsley, R.D. Herbert, A. McCluskey and A. Cusick, Splinting the hand in the functional position after brain impairment: A randomized controlled trial, *Archives of Physical Medicine and Rehabilitation* **84** (2003), 297–302.

[15] G. Nelles, W. Jentzen, M. Jueptner et al., Arm training induced brain plasticity in stroke studied with serial positron emission tomography, *NeuroImage* **13** (2001), 1146–1154.

[16] R.J. Nudo, E.J. Plautz and S.B. Frost, Role of adaptive plasticity in recovery of function after damage to motor cortex, *Muscle Nerve* **24** (2001), 1000–1019.

[17] S.W. O'Driscoll, E. Horii, R. Ness, T.D. Cahalan et al., The relationship between wrist position, grasp size, and grip strength, *The Journal of Hand Surgery* (1991), 169–177.

[18] L. Oujamaa, I. Relave, J. Froger et al., Rehabilitation of arm function after stroke. Literature review, *Annals of Physical and Rehabilitation Medicine* (9 April 2009), (EPub).

[19] N. O'Dwyer, L. Ada and P. Neilson, Spasticity and muscle contracture following stroke, *Brain* **119** (1996), 1737–1749.

[20] Pedretti's 6th edition Occupational Therapy, Practice Skills for Physical Dysfunction Evaluation of Motor Control H.M. Pendleton and W. Schultz-Krohn, 2006.

[21] S.A. Sharp and B. Brouwer, Isokinetic strength training of the hemiparetic knee: effects on function and spasticity, *Archives of Physical Medicine and Rehabilitation* **78** (1997), 1231–1236.

[22] M. Stuart, J.E. Butler, D.F. Collins, J.L. Taylor et al., The history of contraction of the wrist flexors can change cortical excitability, *Journal of Physiology* **545**(3) (2002), 731–737.

[23] E. Taub, Somatosensory deafferentation research with monkeys: Implications for rehabilitation medicine, in: *Behavioral Psychology in Rehabilitation Medicine: Clinical Applications*, New York: Williams & Wilkins, 1980, pp. 371–401.

[24] S.F. Tyson, R.M. Kent. Orthotic devices after stroke and other non- progressive brain lesions. *Cochrane Database Systematic Reviews.* 2009; 1: CD003694.

[25] R.P. Van Peppen, G. Kwakkel, S. Wood-Dauphinee, H.J. Hendriks et al. The impact of physical therapy on functional outcomes after stroke: what's the evidence? *Clinical Rehabilitation.* 2004; 18(8): 833-862.

[26] C.J. Winstein, D.K. Rose, S.M. Tan, R. Lewthwaite et al. A randomized controlled comparison of upper-extremity rehabilitation strategies in acute stroke: a pilot study of immediate and long-term outcomes. *Archives of Physical Medicine and Rehabilitation.* 2004; 85(4): 620-628.

[27] S.L. Wolf, S. Blanton, H. Baer, J. Breshears, A.J. Butler: Repetitive task practice: a critical review of constraint-induced movement therapy in stroke. *Neurologist.* 2002;8(6): 325-338.

[28] S.L. Wolf, C. Winstein, J.P. Miller, E. Taub et al. Effect of constraint-induced movement therapy on upper extremity function 3 to 9 months after stroke. *Journal of the American Medical Association.* 2006; 296: 2095-2104.