CHAPTER V

DISCUSSION

The findings showed that patients with hemiplegia were able to use the HBES and exercise by themselves or with care takers at home. This study also indicated that TSE and ES+TSE regardless of the sequence for 8 weeks of treatment could improve upper extremity function in chronic hemiplegia. It also showed that ES+TSE significantly improved hand functions in the chronic strokes when compared to the TSE alone. In general, significant improvements with treatment are difficult to demonstrate in chronic hemiplegia. We believed that the represented improvements in UE chronic hemiplegia were the effects of the home-based interventions provided in the study. A few reasons may explain this assumption. Firstly, baseline parameters were tested twice prior to interventions which showed no significant difference. Secondly, spontaneous recovery was unlikely to expect after 2 to 3 months poststroke (4, 27), although definitions vary. In addition, patients with stroke who had lost hand function completely for more than 4 to 8 weeks have less than 12% chance of recovery functional use of the UE (4, 92).

Only gender ratio was different when compared between groups. However, recovery of UE function in hemiplegia did not depend on the gender of participant (93).

1. Improvement of mWMFT

mWMFT is used to evaluate UE performance whereas providing insight into joint-specific and total limb movement tasks (75). The UE test in mWMFT quantifies movement ability, timed single- or multiple-joint motions and functional task progressed form proximal to distal joint (75, 76). The mWMFT contains 3 parts (speed, strength and functional ability) which functional tasks can be completed (77). The timed joint-segment movements consisted of task 1 to 6; the timed integrative functional movements consisted of task 7 to 15. This test was developed to assess the impact of forced use on recovery of UE function in chronic stroke. Movement times of mWMFT in the present study were about 800-1,000 sec or about 50-60 sec of each item. These data indicated that our participants had severe UE function (13 in 20 of MAS-UA and 17 in 20 of MAS-H less than or equal score 3) when compared to others such as Lin et al (79) reported mWMFT-sec 7.05 sec of each item at pretreatment.

Patients who received the ES+TSE could perform the mWMFT about 100 seconds faster than those in the TSE alone. Lin and coworkers (79) reported that, the mean change scores of a stroke group should achieve 1.5 to 2 seconds of each item in the mWMFT-sec and 0.2 to 0.4 scores of each item in the mWMFT-FA to be regarded as clinically important changes. Thus, the present study showed marked clinically changes in both mWMFT-sec (-111.4 sec or -7.43 sec of each item) and mWMFT-FA (3.5 scores or 0.23 scores of each item) when patients received the ES+TSE at the second 4-week of group A. Similarly, this clinical significance also demonstrated and at the first 4-week of group B (-120.9 sec or -8.06 sec of each item and 4.4 scores or 0.29 scores of each item for mWMFT-sec and mWMFT-FA, respectively). For TSE alone, the finding showed only changes in mWMFT-FA in both groups which was equal to 2.6 and 1.1 scores. Furthermore, the changes of mWMFT-sec after 8-week training had a very large Cohen's effect size (1.29) and mWMFT-FA improvement was also found as large Cohen's effect size (0.93). In addition, 70% of participants expressed positive attitude that they felt easier to move a paretic arm after treatment.

When compared with the previous studies which examined the effects of home program using electrical stimulation. The findings of the present study were in consistent to Hedman and Sullivan (94). Furthermore, our results were also agreed with Dunning et al (23) and Hill-Hermann (95). However, these studies were only case reports which suggested that home-based electrical stimulation with task-specific training could improve recovery of UE in chronic hemiplegia.

The findings of the present study were also consistent to Alon et al (17) on recovery in mild and moderated impairments on UE acute hemiplegia (10.9±4.4 days) with individual tailored task-oriented program combined with FES. They reported that mild or moderate impairment of UE acute hemiplegic patients could improve functional movement after FES combined with task-specific training but remain unchange improvements in stroke patients who severe hand functions (17, 26). They suggested that patients with severe motor paresis might require prolonged task-specific FES training. Pang et al (96) also found that only the mild and moderate impairment patients had significant changes (P=0.001 and P=0.002, respectively) in mWMFT-FA but not in severe impairment. However, they did not find change in mWMFT-sec in mild, moderate, and severe impairment patients. Pang et al used electrical stimulation on the wrist extensors only in the patients with severe impairment. Although their treatment duration was 19 weeks, they did not show significant change in severe impairment patients.

This discrepancy of HBES of pervious studied (17, 20, 23, 24, 26) was likely explained by differences in measured outcome parameters and time since onset. In our study, functional outcome parameters were mWMFT and MAS, whereas Alon et al (17) were determined using the Box & Blocks and the Jebsen-Taylor light object lift. These two tests are suitable for participants who can generate functional ability to grasp, hold, move and place objects. The selected assessments used in Alon et al study were not suitable for patients with severe impairment. For the time since onset, the present study indicated a period of at least two months after onset as chronic hemiplegia, same as Hashimoto et al (27). However, other study designated the period of three or six months (97, 98). The essence is most of natural recovery appeared between three to six weeks after onset (4). Thus, the effects of HBES can be different in the studies using acute or subacute patients (17, 26) as compared to the chronic hemiplegia.

2. Improvement of Motor Assessment Scale

The MAS represents UE functional abilities in the 7-level scores (0 to 6). In addition, Sabari et al (99) also recommended that some levels of MAS-H (criteria 1, 4 and 5) are difficult hand movements. Thus, its sensitivity to detect any changes is lesser than mWMFT. Although the mWMFT showed significant improvement, the MAS did not change after 4-week training in both groups. This unchanged score might be partly due to the short duration of treatment, and the high level of UE impairments in our participants. Furthermore, participants need more effort for controlling over greater numbers of degree of freedom, thereby enhancing the difficulty level of motor tasks. Thus, this test might not be sensitive enough to detect minimal changes improvements in chronic stroke who had poor hand functions. The majority of our participants (13/20 of MAS-UA and 17/20 of MAS-H) could not generate force to grasp or release an object. Thus, the MAS-H did not statistically distinct change either when patients received the TSE or the ES+TSE treatment for 4-weeks.

However, both of MAS-UA and MAS-H improved significantly after 8 weeks of training in group A but did not find in group B. The reasons might be due to duration of treatment long enough for muscular adaptations and progressive assistance exercise training from ES+TSE treatment. Johnson and Selfe (81) suggested that the MAS might be favored in higher level of mobility. Patients in group A received exercise for 4 weeks prior to the ES+TSE treatment, thus, muscles and joints mobility have been prepared before the progressive assisted exercise training from ES+TSE. Unchanged score of MAS of ES+TSE treatment in group B might be partly due to the second 4-week of TSE alone may not be sufficient to maintain or generated functional gains.

3. Improvement of range of motion

There were significant improvements in the AROM and PROM of the shoulder, the elbow and the wrist joints in both groups. It has been reported that TSE and ES+TSE regained joint mobility, thereby boosting motor functions (17, 20). Especially, hemiplegic patients who were received ES+TSE treatment in both groups. These results were in agreement with others (24, 25). TSE of the study consists of 2 parts: stretching part (7 actions) and exercises part, that is, repetitive of active assisted and or free active exercises (90). Stretching was a potential connection with the development of increased ROM and therefore provided an effective flexibility. Improvement of ROM could be resulted in both of active and passive stretching. Static stretching 10 seconds provided sufficient to elicit a Golgi tendon organ response that improved ROM (100). Positive changes on AROM in the present study expected that enabling repetitive muscle contraction would improve strength led to functional performance. Flexibility or ROM exercises were used to establish a functional range of motion before proceeding to progressive exercises. Ring and Rosenthal (19) showed significantly increase in the shoulder flexion, wrist flexion and extension after FES training in stroke patients who had moderate to severe UE paresis 3 to 6 moths. Thus, patients who received both TSE and ES+TSE treatments demonstrated improvement in both AROM and PROM.

4. Decrease of spasticity

The findings demonstrated that spasticity of wrist flexors only decreased in group A (week 5^{th} vs 9^{th}) but did not found in group B. The present study also found improvement of spasticity of wrist flexor muscles in ES+TSE treatment when compared to TSE alone (*P*=0.005). Stroke patients typically show abnormal muscle synergies: reduced specificity of muscle activation, high levels of agonist and antagonist co-contraction and abnormal regulation and specification of stretch reflex threshold (101). Barker et al (101) found that stroke patients showed increase triceps activation and increased ratio of triceps to biceps activation while performing reaching after using a non-robotic upper limb training device with surface EMG triggered functional electrical stimulation. Electrical stimulation may help stimulated hand opening that describing in the mechanism of reciprocal inhibition of the finger flexor muscles when extensor muscles in hemiplegic patients are stimulated (20, 24). Thus, ES is not only facilitates reciprocal inhibition of antagonist muscle but also decrease antagonist muscle tone (24). In addition, spasticity of wrist flexors in group A was higher (median=2) than other muscles within group and between group. It may be easier to promote the reduction of spasticity in the higher level of muscle tone.

The unchanged spasticity in other group of muscles after training might be due to the relatively low level of modified Ashworth scale (median=1). Previously researches also reported unchange of spasticity after trained using FES (20, 60, 102).

5. Improvement of sensation

The results found that one patient in group A improved from impaired in light touch and pinprick sensation to intact sensation at week 9th. Similarly, only one patient improved sensation at week 9th in group B. Sensory system deficits might be resulted as well as impaired motor function after stroke (25). Previous studies (20, 25, 103) suggested that ES delivered at both sensory and motor amplitude has been proved to reduce impairment and improved arm function after stroke. Sensory and motor improvements might occur in patients with chronic hemiplegia (20). Sensory input during stimulation-assisted task, that is, during reaching, grasping, or releasing an object provided activation of cutaneous receptors. Moreover, afferent inputs from the contracting muscles, and from hand contact with the objects used in the task also facilitated sensory afferent. Thus, the combined both motor and sensory amplitude electrical stimulation represented an increase in the amount of afferent inputs that hemiplegic patients had previously been experiencing. This process could have contributed to improvements in sensation.

However, our study did not show sensory improvement obviously. The findings of improvement of sensation were uncertain.

6. Improvement of the goal functional task

Functional ability was measured using either movement time or AROM. Each patient was assigned to perform only the single functional task which was selected by the researcher according to patient's ability. Progression of performance was compared to baseline as percentage of changes. The improvement of performance was shown after the end of 8 weeks of treatment. However, we found that only a single task was not a good criterion to assess functional ability. The defined task may be too difficult or too easy in some of patients. Furthermore, only the quantitative parameter, that is, movement time or AROM, was measured. Thus, assessment of quality of movement is required to detect the real effect of treatment. Furthermore, improvement of functional tasks can be determined from the mWMFT and MAS. Thus, it is not reasonable to make a conclusion from this part of results.

7. Proposed mechanism of ES and TSE

We postulated that several factors were contributed to the superior effects of ES+TSE. Firstly, the patient was able to completely practice the task-specific with voluntary effort because patient's voluntary movement was a key factor of the training. Functional improvement was found in a previous study in which patients were advised to attempt voluntary muscles contractions during electrical stimulation as well as electromyography-triggered ES (24). Secondly, ES+TSE might have a direct effect leading to increase muscles strength, reduction in muscle tone, and to improve motor control due to patients attempt to control functional ability. Strength gains relative with exercise had historically attributed two factors: increased neural recruitment and increased muscle fiber hypertrophy. Electrical stimulation may simply be a convenient method of repetitive muscle contraction and stretching of muscle groups (18). Thirdly, progressive tailored individual exercise was important to improved UE functional abilities. This study exercise consisted of passive ROM, active assisted, and functional task exercise which would facilitate quality of UE movements. These reasons might result to improve in mWMFT, MAS, AROM, and PROM.

A decrease in time completed task and an increase in functional ability of mWMFT were observed in both of group A and group B after 8 weeks. It appears that these improvements were observed across the participants who showed no change in AROM. Whether these improved motions resulted from muscle tissues or neurological changes remains a question to be answered. However, repeated contractions during electrical stimulation in combination with exercise may be more effective than exercise alone. Active exercise with the stimulation may help strengthen the active muscle fibers and reduce passive joint stiffness (20). Alternatively, neural adaptations may also involve by reducing co-contraction of agonists and antagonists and increasing agonist excitation (24, 101). The other possible mechanism may be resulted from the improvement of afferent activation (25). Cutaneous receptors were activated during stimulation-assisted motion and during the active movements. It was also reported that the proprioceptive and cutaneous impulse during the training may be induced long-term potentiation (LTP) phenomena in the sensory cortex (104). The increased excitability of a specific subset of cortical neurons may facilitate the muscles involved in the movement (104).

8. Participants' satisfaction with TSE and ES+TSE

The participants' satisfaction were evaluated using the defined questionnaire. Most of participants expressed similar positive attitude toward TSE and ES+TSE programs. All of them agreed (very agree to extremely agree) that the programs were easy to use (65% in TSE and 70% in ES+TSE) and helpful to improve their functional abilities (75% both TSE and ES+TSE). The contents included in both of TSE alone and ES+TSE treatment were considerably suitable to use by themselves or their care takers. In addition, the electrical stimulator was friendly-user. The task-specific program, an appointment of each week, and the manual book were also helpful. Thereby, participants were highly satisfied with our intervention. Moreover, some patients preferred to keep performing more than 4-week period such as 12 to 24 weeks.

Some patients reported that they were able to used an affected arm such as picking up a spoon, grasping a can to mouth, picking up small beans, or washing dishes after 8-week training. However, this study did not record their abilities in activity daily living (ADL).

The high levels of satisfaction in both of the TES and ES+TSE were consistent with the high self-treatment compliance, that is, each patient performed self-practiced no less than 3 hours/week. This high satisfaction level might be a reason for the participants to keep performing continuously throughout the study period. In addition, the improvements in outcome measures in this study supported the high level of satisfaction with home-based training.

CONCLUSION

In conclusion, our present study shows for the first time that randomized controlled study of home-based electrical stimulation in combination with task-specific exercise significantly improved motor abilities in chronic post-stroke upper extremity of hemiplegia. Results also suggested that improvements in UE functions during 4-week in ES+TSE treatment were significantly more than 4-week in TSE alone. The effects of ES+TSE were independent of changes in sensory perception and joint range of motion. The 4 weeks of TSE prior to 4 weeks of ES+TSE may result in a better outcome when compared to the reverse order of intervention sequence, that is, ES+TSE followed by TSE. However, further research is required to confirm the effect of treatment order. Moreover, our new innovative electrical stimulator has been proved applicable, cost-effective, and user-friendly product.

LIMITATIONS AND SUGGESTIONS

Although, this is the first randomized controlled study to evaluate the effects of home-based electrical stimulation combined with task-specific program on upper extremity function in chronic hemiplegia, some points may be considered as limitations in the study.

1. Long-term evaluation, the follow-up interval should be further applied after the end of 8-week intervention. Whether or not a greater improvement in the outcome measures of TSE and ES+TSE treatments can be attained if study period is extended remained unknown.

2. Patients with hemiplegia are very heterogeneous. We do not know how other factors such as pathology location, extent, and age of lesion affect the results. In addition, participants' medical problems and their family supports may also involve in their recovery.

3. Although, baseline outcome parameters showed no significant difference between groups, and most of patients were considered as chronic hemiplegia, their functional abilities were varied from mild to severe impairments. The difference of the initial mWMFT-sec and mWMFT-FA may affect their recovery. Thus, a more certain conclusion of the treatment may be determined if all patients have similar severity of impairments.

4. A larger number of sample sizes and longer duration of treatment than 8 weeks of treatment should be considered.

5. All of our patients lived in their home and because of the long duration post-onset, they usually had their own self-treated exercise programs. Thus, it may not be appealing to recruit them as the control group which only received TSE alone. Most

of participants wanted to join the research program because of the home-based electrical stimulation protocol. This condition made us decide to use the randomized controlled with crossover study. However, there was still a chance that some protocols might be repeated more often than others, especially when the sample size was only twenty. Thus, we also counterbalanced the treatment conditions. Furthermore, motor recovery in hemiplegia is a long term process and the effects of training cannot reverse in a short period. The present study could not set a washout period due to the limitation of time. However, to eliminate any carryover effect, we analysed the data by subtracting pre-treatment data from the post-4 week data. Any contributing factors, such as motor learning, carryover, or fatigue were similar in both groups after the end of 8-week training. Thus, the present study can be confirmed the superior effect of ES+TSE when compared to TSE alone.

Despite, we did not intend to prove the sequence of treatment, the results may suggest that cessation of the electrical stimulation protocol resulted in a delay of motor recovery. This situation may similar to the deconditioning period after stop training. Whether the longer stimulation period (more than 4 weeks) can maintain motor ability gains remained unknown.

6. To determine the effect of treatment order, a washout period should be set before starting the new intervention. We suggest that a short duration of washout period with repeated measurements is required.