

How long does the Prevention Effect Last? A Comparison of two Case Studies of different FES Stimulation Frequencies in Stroke Shoulder Subluxation Follow up Period

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Abstract— there is strong evidence on the positive effect of functional electrical stimulation (FES) in preventing shoulder subluxation (SS) following stroke. However, the extent of such intervention has not been weekly documented with regards to different stimulation frequencies. It is unknown whether high or low frequency (35 Hz or 20 Hz) has better potential in maintaining the FES effect in preventing SS during the follow-up period. Two participants underwent standard prescribed physiotherapy sessions in a rehabilitation centre during their hospitalization period. Electrical stimulation was administered to their supraspinatus and posterior deltoid muscles for up to 2 hours a day for 4 weeks. All stimulation parameters were set constant except the stimulation current, which depended on the subject tolerance, and stimulation frequency, which was set to high (35Hz: Subject A) and low (20 Hz: Subject B). No SS among the intervened subjects during the 4 weeks FES therapy period. The high (35 Hz) stimulation frequency prevented subluxation until the end of 4 weeks follow up period in Subject A while low stimulation (20 Hz) frequency stimulation maintained the effect for up to 2 weeks in Subject B. The effect of FES on SS could be maintained up to 4 weeks upon withdrawal without undergoing subsequent FES therapy. Given all parameters fixed and the stimulation current dependent on the subject's tolerance, high frequency stimulation (35Hz) may be recommended in a subluxation prevention programs to further maintain the stability of the shoulder joint.

Index Terms— Functional electrical stimulation (FES), shoulder subluxation (SS), stimulation frequency, physiotherapy, FES therapy.

I. INTRODUCTION

Shoulder subluxation (SS) is one of the common complications in post-stroke hemiplegic patients. Functional electrical stimulation (FES) has been established as a therapeutic intervention to prevent (SS) and shoulder pain. There is strong evidence that electrical stimulation does reduce and helps to prevent the development of SS [1]. Linn et al reported in their study that even though subluxation occurred significantly in the control group rather than the treatment group, which suggested that subluxation can be prevented by FES, the result was not carried over the withdrawal follow-up period [2, 3]. The finding was confirmed by Wang et al in

which subluxation reoccurred during the 6 weeks intermittent period before the second FES therapy [4]. In essence, very few studies have demonstrated the long term maintenance effect of this therapy and it is still unclear how long the SS prevention effect can be maintained as monitored on a weekly basis.

The individual stimulation parameters might also have significantly affected the findings of each reported studies. A literature comparison reflected inconsistent FES stimulation parameter settings and protocol among all reported studies. This might be related to the particular FES instrument model that was used in each study as well as the respective clinical setting. While the efficacy of FES in preventing SS was strongly established, along with its negative long term carry-over effect upon withdrawal, the authors suggested that the stimulation parameters might be optimized instead to gain most benefit from the known clinical prescription effect of FES in acute stroke individuals.

Consequently, this study reported two case study comparisons of FES intervention for prevention of SS to determine how long the effect can be maintained after the FES intervention withdrawal with respect to the controllable parameters. In this case, the stimulation frequency was set as the varied parameter because it has been shown to effect muscle fatigue and strength of contraction [5] thus could be the primary factor in determining the carry over effect, and was independent of subject's sensational tolerance.

II. METHODS

Three male subjects, aged 47 ± 11 years old, with right sided hemiplegia were recruited from acute stroke unit of the University Malaya Medical Centre. Subjects were recruited from acute stroke unit of University of Malaya hospital and were randomly assigned as control subject (Subject C) and two FES treatment subjects at two different FES stimulation frequencies (20 Hz for Subject A and 35 Hz for Subject B) for 4 weeks. Subject C was administered conventional physiotherapy and occupational therapy only while additional FES therapy was prescribed to Subjects A and B. The published inclusion and exclusion criteria were adopted in this study. Detailed treatment procedure was explained to all

participants and informed consent was obtained as approved by University of Malaya Ethics Committee.

FES therapy was administered 2 times a day with rest interval of at least 1 hour on the supraspinatus and posterior deltoid muscles, for one hour per session. Different stimulation current intensity were applied for each subject depending on their current level of tolerance while the other parameters were set similar for both subjects (Symmetric biphasic pulse, ON: OFF ratio 6:18 sec (1:3), duty cycle: 6 seconds on, ramp up: 3 seconds, ramp down: 3 seconds, 18 seconds off) except the stimulation frequencies.

Studies reported that although higher stimulation frequency of more than 35 Hz can provide high muscle contraction and muscle torque, muscle fatigue is achieved easily within 30 minutes of such stimulation. Therefore, in this study the high frequency limit was set at 35 Hz. On the other hand, low frequency limit was set at 20 Hz based on previous literature reports [5, 6], as the physiological frequency in order to achieve contraction in normal muscle is between 10 and 30 Hz. Physiotherapy and occupational therapy was continued in all participants during the follow up period.

III. RESULTS

A. Outcome measures

Shoulder subluxation was assessed using anterior-posterior shoulder X-ray using Van Langenberghe classification before the start of FES therapy. The distance between the inferior border of acromion and superior border of humerus measured by X-ray was recorded as D1. The shoulder joint was further monitored for 4 weeks after the treatment period, i.e. during the follow up period, using ultrasound to minimize subject's exposure to X-ray radiation. The ultrasound measured distance, D2, was measured weekly to monitor the development of shoulder subluxation upon FES withdrawal. D1 was measured at baseline before FES therapy, at the end of the 4 weeks therapy and at the end of the 4 weeks follow up period (Figure 1).

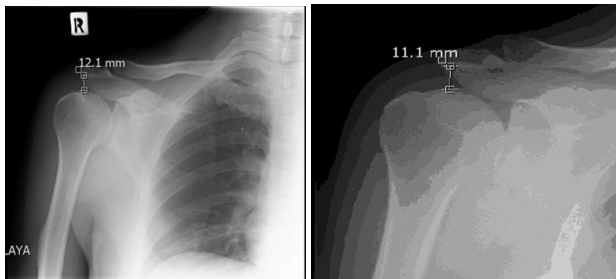


Fig. 1. X-ray result showing D1 value (a) after FES therapy and (b) Post follow-up, in Subject.

B. Discussion

The stimulation current levels were administered according to each subject's tolerance (Subject A: 27 to 40mA; Subject B: 8 to 12 mA). No shoulder subluxation was reported in all subjects at the beginning of the therapy. After 4 weeks of FES therapy no subluxation was observed in both intervened subjects. The degree of subluxation increased after one month

in the control subject, while remained the same for Subjects A and B with differences only in post-follow up. measures (Table 1). During follow up period, D2 values increased in both subjects throughout the 3 weeks.

In this study, the application of low frequency stimulation (20 Hz) was found to be insufficient to obtain the necessary contraction to maintain joint stability although it is within the range of other published studies [5, 6], and its onset of fatigue was delayed compared to higher frequencies. This study also highlighted that both 20 Hz and 35 Hz frequencies successfully prevented subluxation as reported by prior studies. The different responses might be the carry over effect which was observed during the follow up period. This has not been previously reported in the literature. Additionally, in published studies [5, 7, 8], the total stimulation time was up to 6 to 7 hours per day. In this report, the total stimulation time was two hours per day. This highlighted the effectiveness of shorter FES intervention time which is consistent with the normal hospitalization duration for the acute stroke patients of normally 2 to 3 weeks. It also appeared that longer stimulation duration might not be required to prevent subluxation, but the conclusion should be drawn from a larger sample size of properly designed clinical studies.

It worth highlighting that Subject A was able to withstand higher stimulation amplitude more than Subject B. This implied that the deeper muscle fibers were stimulated by the increased amplitude and the desired muscle contraction was acquired although 20 Hz was considered as low stimulation frequency. However, 20 Hz was not sufficient to produce high contraction force even though the onset of fatigue is slow. Although the onset of fatigue in 35 Hz frequency stimulation was faster than 20 Hz frequency stimulation, the desired muscle contraction was achieved in Subject B, which is important to hold the head of the humerus in glenoid fossa. Therefore high frequency FES stimulation may be more preferable in preventing the shoulder subluxation for longer in acute stroke patients.

TABLE I. Distance between the inferior border of acromion and superior border of humerus measured in mm by X-ray and ultrasound

Subject	Week	0	4	5	6	7	8
	Event measures	Pre-FES	Post-FES	Follow Up			
	Measurands	X-Ray,D1(mm)		Ultrasound,D2 (mm)			D1 X-Ray, (mm)
A	20Hz	15.8	15.8	11.1	14.1	17.2	18
B	35 Hz	15.3	12.1	14	24	21	11.1
C	Control	8.8	15	-	-	-	23.2

IV. CONCLUSION

The case study suggested that high stimulation frequency (35 Hz) may be more beneficial in subluxation prevention prescription as it potentially maintains the stability of the shoulder joint for a longer duration compared to a lower frequency (20Hz). A randomized controlled trial has to be conducted to verify this observation.

ACKNOWLEDGMENT

This study was financially supported by the Ministry of Higher Education, Malaysia and University of Malaya through HIR Grant No. UM.C/625/1/HIR/MOHE/ENG/39.

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