Effect of Sling Rehabilitation Exercises with Vibration Balls on the Upper Limb Muscle Activity for disabled people

Ju-Hwan Oh, Tae-Kyu Kwon

***Abstract*—**The purpose of the present study is to verify the effectiveness of a muscle activity by applying the complex functional exercise methods and active rehabilitation methods of sling exercises in accordance with the provision of vibration for people with myelopathy. Study subjects were 16 men in their 40s and 50s with lower limb disabilities. They were randomly divided into a sling exercise group (SG n=4), a sling with low frequency vibration group (SLVG n=4), a sling with mid-frequency vibration group (SMVG n=4), and a sling with high frequency group (SHVG n=4). The anterior deltoid (AD), the posterior deltoid (PD), the pectoralis major (PM), the upper trapezius (UT), the latissimus dorsi (LD), the triceps (TC), the biceps (BC), and the multifidus (MF) were measured to compare and analyze muscle activity. One-way ANOVA was conducted to compare the recovery effects by using SPSS 18.0 Korea. The statistical significance was accepted at $p<0.05$. Our results showed that the low intensity vibration (30Hz) was the effective stimuli for open kinetic chain exercises, while vibration stimuli of an mid intensity (50Hz) were the effective vibration for closed kinetic chain.

***Keywords*—**sling exercise therapy(SET), vibration ball, muscle activity, rehabilitation exercise.

I. Introduction

Myelopathy involves paralysis, spasticity, or paresis in the damaged area or part of the body below it when spinal cord or sensory, and motor nerve disabilities occur due to a disease or a sudden accident (traffic accidents, sports injuries, and industrial accidents among others) [1]. Spinal cord injuries display differing physical responses depending on the damaged area, and for cervical spinal cord injuries, complex motor abilities decline because dysfunction occurs in terms of thermoregulation and the whole body. In particular, more people with damage to T6 or higher suffer from difficulties in daily life and instrumental activities due to the considerable decline of health-related fitness (muscle strength, muscle endurance, flexibility, cardiovascular endurance) and motor function fitness (power, agility, and balance) as a result of the complex issues in the spinal and sensory nerves [2]. Also, most people with myelopathy perform motions and movement in daily life by relying on a wheelchair due to their lower limb disabilities. In general, the isometric muscles that affect the residual functions of the upper limbs are higher than the averages of people with a sedentary lifestyle or people without disabilities [3]. However, the upper limb muscle strength of people with myelopathy does not tend to be high without fail but differs depending on the degree and type of disability [4]. Ultimately, if muscle strength is lacking among the residual functions of the upper limbs, it can effect musculoskeletal diseases, increases in muscle fatigue, and decreases in movement efficiency [5], and hence, it is necessary to continue the effort to develop and apply exercise programs that allow people with myelopathy to easily perform daily life and instrumental activities by improving health-related fitness and motor function fitness with a focus on the upper limbs.

Many studies on people with myelopathy continuously report that regular exercise for fixed periods aids the improvement of health-related fitness. In particular, studies applying equipment for improving upper limb functions are being additionally carried out, and their methods include the use of arm ergometers, elastic bands, and functional electrical stimulus through PNF aquatic isokinetic equipment. Elastic bands and aquatic isokinetic equipment make use of spiral patterns to stimulate proprioception which has been verified for its effectiveness with regards to the flexion and extension of the shoulder joints as a method of accelerating normal response. Furthermore, FES has been reported to increase muscle strength by five-fold after applying electrical stimulus for 10 minutes, three times a day, once a week, for six months, with a 50Hz stimulus [6].

However previous studies mostly involve the analysis of the application and effect of rehabilitation exercises methods by utilizing equipment, while studies on functional exercise methods applicable to people with myelopathy by utilizing active (isotonic, isometric) and passive (neural stimulation) forms are lacking. Many studies have verified the effectiveness of body vibration stimulus in terms of neuromuscular stimulus although its effectiveness depending on various motor intensities and vibration stimulus methods is yet to be verified.

Recent exercise trends have continuously suggested functional exercise methods as part of the therapeutic method

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for improving recovery in terms of active and rehabilitative aspects [3]. Proprioceptive neuromuscular facilitation, in particular, is a response facilitation of the neuromuscular mechanism with the purpose of adding proprioceptive stimulation (muscle spindles, golgi tendon organ) which transfers afferent impulses involving muscle length or tension by letting motor system responses to appear.

In this respect, sling exercises can cause static and dynamic muscle contractions and consequently apply neuromuscular stimulus by using suspensions and assistive devices so as to carry out rehabilitation exercises and functional training on unstable environments. Furthermore, as a representative functional exercise method apparatus, vibratory stimulus has the advantage of additionally improving the functions of the neuromuscular system as s mechanism of the tonic vibration reflex (TVR) by changing the exercise intensity (Hz, mm, duration) [4-5].

Because people with myelopathy, in particular, primarily go through neuromuscular damage and secondarily musculoskeletal diseases or various other disabilities, complex exercise stimulus through slings and vibrations can have a synergy effect including proprioception or neuromuscular recovery, which is likely to anticipate a positive effect in terms of body function maintenance and improvement.

Therefore, the purpose of the present study is to verify the effectiveness of a muscle function improvement program by applying complex functional exercise methods and active rehabilitation methods in accordance with the provision of various intensities of sonic-vibration aimed at serving people with myelopathy.

II. Methods

The subjects of the study were 16 men in their 40s and 50s, with lower limb disabilities, without any other particular medical diseases, who had little potent risk factors. The subjects participating in the study underwent open kinetic chain (OKC) and closed kinetic chain (CKC) exercises through sling and were randomly divided into a sling exercise group (SG, n=4), a sling with low frequency vibration group (SLVG, n=4), a sling with mid frequency vibration group (SMVG, n=4), a sling with high frequency vibration group (SLVG, n=4) in accordance with the type of sling exercise and vibration. The physical characteristics of the subjects are indicated by "Table. 1". Before participating in the experiment, all subjects were fully informed of the purpose, methods, and procedures of the experiment and voluntarily signed a participation agreement. Also, the study was conducted under the evaluation (JBNU 2017-02-002-001) of the Institutional Bioethics (IRB) at Chonbuk National University.

III. Measurement

The experiment processes show the changes in muscle activity by party part in accordance with the type of sling exercise in "Fig. 1".

TABLE Ⅰ. CHARACTERISTICS OF THE SUBJECTS

Group	N	Age(yr)M±SD	Weight(kg)M±SD
SG	4	40.2±2.5	65.5±9.3
SLVG	4	40.3±1.8	66.7±8.2
SMVG	4	41.2±2.3	68.5±5.6
SHVG	4	42.1±1.9	64.9±2.8

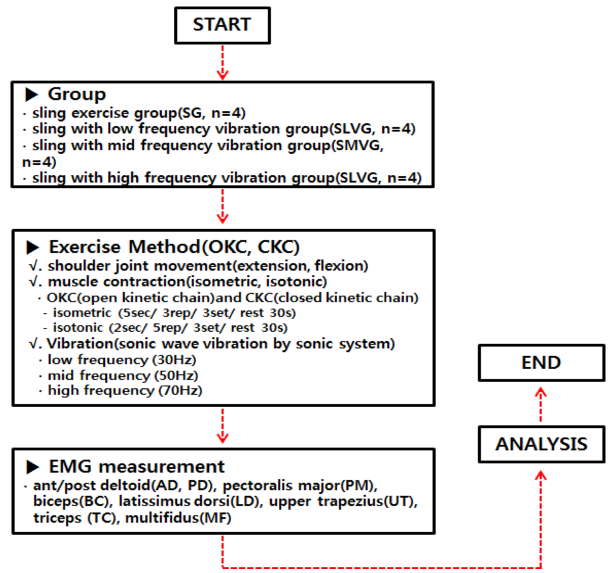


Fig. 1 Block diagram of experimental procedure

Sling exercise types were performed OKC, with further divisions by functional-anatomical movement in terms of the flexion and extension of the shoulder joints, and by muscle contraction type in terms of isometric and isotonic contraction in "Fig. 2". The OKC is a single joint exercise that does not bear any weight and without distal segment fixed and is mainly used during stretching and small muscle development training. The CKC is carried out with the distal segment in a fixed position and is capable of an organic co-contraction of the agonist, antagonist, and synergist muscles. The motion involves shoulder joint at the supine position by using an elastic cord. The isometric was conducted in 3 sets of 3 for 5 seconds at the peak of maximum contraction, while isotonic contraction was conducted in 3 sets of 5 reps in 2 seconds with once second of concentric and once second of eccentric contraction, with the consequent muscle activity being recorded. Furthermore, the rest time between each set was 30 seconds, with the number of reps and sets determined by considering fatigue.

The vibration stimulus (frequency, Hz) provided through the vibration actuator is presented in "Fig. 3". The provided vibration intensity is divided into low frequency (30Hz), mid frequency (50Hz), and high frequency (70Hz) according to the stage set in the vibration ball. The muscle parts that were measured were the anterior deltoid (AD), the posterior deltoid (PD), the pectoralis major (PM), the upper trapezius (UT), the latissimus dorsi (LD), the biceps (BC), the triceps (TC) and the multifidus (MF). In order to block any exterior factors that could affect the result during the experiment, the researchers continuously provided additional verbal and nonverbal feedback and used stopwatches and metronomes to achieve a consistent movement.

Fig. 2 Exercise method of shoulder joint movement in OKC and CKC sling exercise therapy (SET)

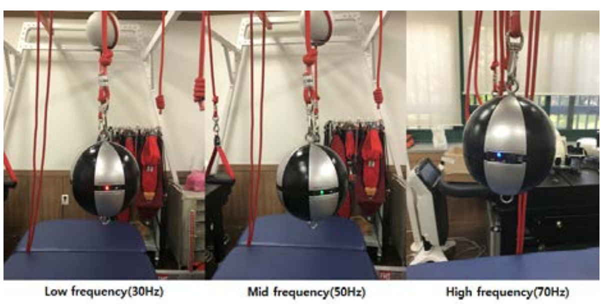


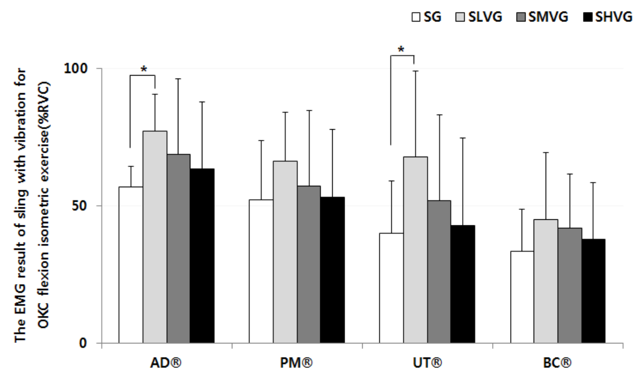
Fig. 3 Type of exercise intensity of sonic wave vibration balls (Hz)

IV. Statistical Analysis

The study calculated averages and standard deviation against the muscle activity results in accordance with the sling exercise and vibration stimulus of each group by using the SPSS 18.0 Korea program to confirm statistical significance. One-way ANOVA was used and applied to comparatively analyze the results of each group, and Bonferroni was used for the post hoc analysis in order to verify specific reliability. The statistical level of significance was set at p<.05.

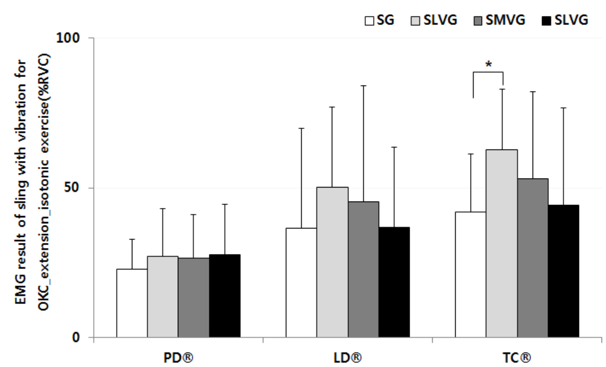
V. Result

The results of the sling with vibration exercise are shown in “Table. 2”. OKC are mainly single joint exercises that are conducted without the distal segment of the body at a fixed position. The isometric of the shoulder joint flexion provides higher muscle activity in the sling exercise that provides vibration stimulus than SG in the AD, the PM, the UT, and the BC. Also, muscle activity was higher in the SLVG and displayed statistically significant differences with SG in the AD and the UT in “Fig. 4”. The isotonic exercise was no statistical difference in the rest of the muscles except for the AD. The results of extension exercise show the muscle activity of all muscles in the SLVG to be higher in comparison with the PD, the LD and the TC of other groups, with the figures for the TC, in particular, displaying a statistically significant difference in isometric contraction in “Fig. 5”.



AD: anterior deltoid / PM: pectoralis major / UT: upper trapezius / BC: biceps

Fig. 4. The result of EMG measurement in OKC flexion (mean ± SD)



PD: posterior deltoid / LD: latissimus dorsi / TC: triceps

Fig. 5. The result of EMG measurement in OKC extension (mean ± SD)

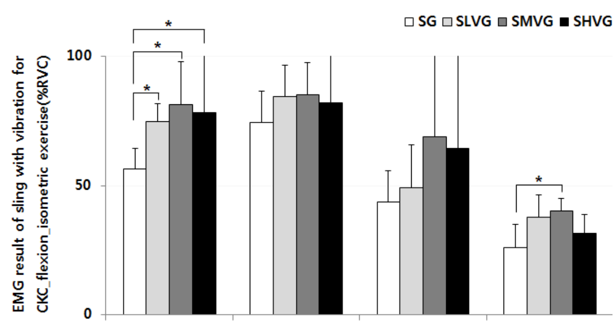


Fig. 6. The result of EMG measurement in CKC flexion (mean ± SD)

TABLE Ⅱ. EMG MEASUREMENT VALUE

Exercise form		Muscle	Group				F	Bonferroni
			SG (n=4)	SLVG (n=4)	SMVG (n=4)	SHVG (n=4)		
OKC (open kinetic chain)	Isometric flexion	AD	57.6±7.1	77.1±13.7	69.0±27.3	63.5±24.4	2.657*	SG < SLVG
		PM	52.3±21.4	66.4±17.8	57.4±31.4	53.2±24.6	1.193	
		UT	40.0±19.0	67.7±31.4	52.1±31.0	42.8±31.8	4.392*	SG < SLVG
		BC	33.3±15.5	45.1±24.3	42.1±19.4	37.8±20.7	1.496	
	Isotonic flexion	AD	58.5±21.1	89.4±10.0	86.8±13.0	85.0±13.3	3.178*	SG < SLVG
		PM	80.9±16.4	83.5±14.8	76.5±11.0	71.9±12.7	.346	
		UT	51.7±28.1	66.7±13.7	64.7±13.1	63.0±10.1	.624	
		BC	47.2±27.8	65.0±11.2	48.7±23.3	44.3±12.2	2.511	
	Isometric extension	PD	19.3±11.9	25.8±11.5	21.4±12.1	22.4±12.8	.886	
		LD	31.0±31.0	32.2±29.0	28.7±22.9	30.7±26.1	.051	
		TC	47.1±31.1	72.5±4.5	53.9±22.5	48.7±23.5	.636	
	Isotonic extension	PD	22.3±9.9	27.1±16.0	26.7±14.3	27.8±16.6	.592	
		LD	36.5±33.3	50.1±26.8	45.5±38.7	36.9±26.8	.457	
		TC	42.1±19.1	62.8±20.3	53.0±29.2	44.3±32.5	5.152*	SG < SLVG
CKC (closed kinetic chain)	Isometric flexion	AD	56.5±7.9	74.9±6.7	81.5±16.4	78.2±24.7	6.649*	SG <SLVG SG <SMVG SG <SHVG
		PD	74.5±12.1	84.4±12.1	85.0±12.5	81.9±18.4	1.565	
		UT	43.6±11.9	49.3±16.4	68.8±39.5	64.3±43.2	1.960	
		MF	25.8±9.0	37.6±8.9	40.1±4.8	31.3±7.5	9.015*	SG <SMVG
	Isotonic flexion	AD	65.6±4.6	81.1±9.2	80.4±55.7	85.6±14.9	1.194	
		PD	76.9±16.0	94.4±16.4	92.9±48.8	87.1±15.1	1.239	
		UT	68.9±13.2	92.0±21.1	90.5±48.5	86.1±9.0	.209	
		MF	36.1±32.7	87.1±18.9	38.5±46.9	40.9±20.0	.105	
	Isometric extension	PD	42.3±7.0	49.6±11.7	57.7±6.5	45.4±12.5	2.765	
		LD	59.0±0.8	71.3±6.2	79.2±9.3	76.4±3.2	13.945*	SG <SLVG SG <SMVG SG <SHVG
		MF	44.6±8.1	46.7±10.9	47.4±6.5	45.0±5.4	.163	
	Isotonic extension	PD	57.2±12.1	74.8±46.9	76.5±29.1	71.9±27.7	.468	
		LD	47.2±27.8	65.0±31.0	75.5±23.5	44.3±22.7	1.873	
		MF	17.5±7.7	17.6±8.2	19.9±2.8	15.9±6.4	.365	

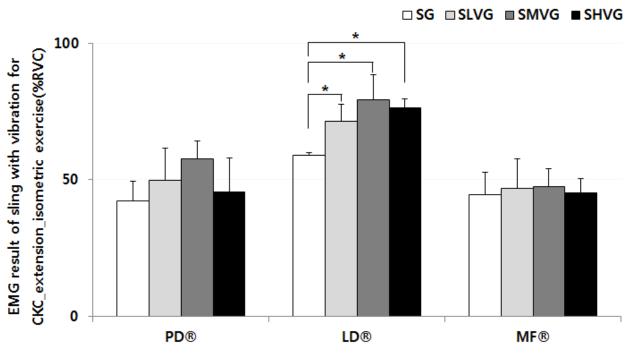


Fig. 7. The result of EMG measurement in CKC extension (mean ± SD)

The CKC is carried out with distal segment of the body at a fixed position, and because it is capable of simultaneous contraction due to its multi-joint form, it provided much help during rehabilitation exercise and training. The result of isometric and isotonic contraction during flexion and extension of the shoulder joints are presented in “Fig. 6”, “Fig. 7”. During flexion, the activity of most muscles was high for the SMVG, with the AD and MF displaying statistically significant differences. During extension, the activity of most muscles was likewise high for the SMVG, with the LD particularly statistically significant differences.

I. Discussion

Most people with myelopathy live their daily lives by depending on a wheelchair and display, in complexity, damage to nervous system. Therefore, as a therapeutic method for restoring active mobility, functional training and rehabilitation capable of activation and optimizing the sensory information of the body are highlighted. The sling, which is a method that can fulfill such a demand, can be applied as a functional training method. As an exercise that enables passive therapy through the use of various assistive devices or a swinging line hung from the ceiling, as well as a method that encourage the patients themselves to participate in active therapy, it can be an effective device for relaxation, range of motion improvement, sensory integration, and muscle strengthening [7-8]. Furthermore, vibration increase the gravitational load on the neuromuscular system as in muscle strength training by increasing acceleration through the use of the force that mechanically occurs. The body perceives such vibrations through muscles, displays an adaptive response in order to buffer the vibrations, and thereby brings about functional improvement in the neuromuscular system by generating a tonic vibration reflex [9-11].

Therefore, the improvement of neuromuscular functions through proprioceptive stimulus and vibration stimulus by providing the active rehabilitation exercises of the sling is an efficient functional complex exercise applicable to people with myelopathy. The results of the flexion exercises of the shoulder joint show that most muscles during isometric contraction display a higher muscle activity in the group that is additionally provided with the vibration rather than the group that is provided only with the sling, and, the comparison between SLVG and SG, in particular, reveals statistically significant difference for the AD and UT. Although the SLVG scored a higher muscle activity than the other groups during isotonic, it was not a statistically significant difference except for the AD. Result of the extension exercise reveals a high muscle activity for by the SLVG in the PD, LD, and TC, with the TC displaying statistically significant differences in the SLVG rather than the SG in isotonic exercise.

Previous studies continuously conducted research on the efficient stimulus of vibration intensities. Considering the result of these studies showing significant increases in the muscle activity of the lower limb at 30Hz along with a temporary effectiveness study stating improvements in muscle strength as a result of proving 15-30Hz [12-13], these studies support the results of the present study. The form of muscles provided to the sling has a mechanism incapable of providing a vibration at the directly desired intensity to the body. One of the reasons is the damping phenomenon of the string that occurs depending on the differences in skin texture and the joints of the body. This mainly occurs in the form of single joint exercises, and such a result is arrived at because the damping phenomenon of the string’s vibration transmitted to the body from low intensity vibration stimulus decreases.

The SMVG during CKC sling exercise displayed a high muscle activity in the AD, PD, UT, and the MF in terms of muscle contraction by the shoulder joint flexion. In comparison with the SG, SMVG displayed statistically significant differences in the AD and MF. However, unlike the results of the OKC exercise, the effectiveness of the vibration stimulus was proven at 50Hz. Also, the muscle activity of the PD, LD, and the MF was higher of extension in the SMVG. Also, the LD particularly statistically significant differences in isometric extension exercise. Furthermore, most people with spinal cord injuries suffer from areas that are incapable of receiving the feeling of muscle contractions due to paralysis of the nerves of the spine. In particular, the disabled people who must perform daily life and function movements by relying on wheelchairs have the need to activate the MF in order to maintain the stability of their upper limbs.

This study was determined that sling exercise and vibrations sufficiently perform the role rehabilitation exercise in that they display statistically significant differences in muscle activity and particular vibration stimulus. A previous study on the chronic an effectiveness of vibration stimulus of 30-40Hz [14]. However, the results proved effectiveness at a lower intensity than the present study. Sling transmit vibration to the body in the form of string which is unlike whole body vibration, and the transmission of vibrations through both means can cause damping to appear depending on skin shape, texture, and joints.

Therefore, mid intensity vibration (50Hz), as opposed to low intensity vibration (30Hz), can decrease the reduction phenomenon of vibration transmission as a result of damping, delivering a more effective stimulus to the body.

The present study which provides vibration stimulus to the string carries limitations. First, people with myelopathy are not familiar with using exercises involving the sling, so they face difficulties performing the accurate motions aiming the target muscles. Second, the study carried out its experimentation by designating a set frequency of low (30Hz), mid (50Hz), and high (70Hz) as the transmission from of vibration stimulus during sling exercise, and the failure to verify effectiveness in relation to specific string vibration is an additional limitation of the study.

II. Conclusion

The purpose of the present study is to provide reliable data on effective rehabilitation exercise methods by simultaneously conducting sling exercises and vibration stimulus for the recovery of residual functions in people with spinal cord injuries. The study arrived at the following conclusions.

First, the results of applying OKC exercise found that the muscle activity of the AD, PM, UT, BC, PD, LD, and MF appeared slightly higher in the SLVG. Furthermore, comparisons with SG found that the AD, UT, and MF were higher slightly for the SLVG, displaying statistically significant differences as well.

Second, the result of applying CKC exercise found that the activity of most muscles was higher for the SMVG, with the AD, PM, and the MF, in particular, displaying statistically significant differences. Ultimately, low intensity strings for OKC and mid intensity vibration stimulus for CKC exercise were effective for the body.

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