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ORIGINAL

The Effect of Sling Exercise Therapy with Vibration Balls on Upper Limb Muscle Activity for Paraplegia-Spinal Cord Injury

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Objective: The purpose of the present study is to investigate the effect of a muscle activity by applying the complex exercise method of sling in accordance with the provision of various vibration intensities for paraplegia-spinal cord injury.

Method: The subjects of the study were 15 men in their 40s and 50s with lower limb disabilities and low potential risk, who 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) in accordance with the provision of slings and vibration stimuli. The vibratory intensity provided was divided into low frequency (30 Hz), mid-frequency (50 Hz), and high frequency (70 Hz). The anterior deltoid (AD), the posterior deltoid (PD), the pectoralis major (PM), the upper trapezius (UT), the latissimus dorsi (LD), and the multifidus (MF) were measured to compare and analyze muscle activity.

Results: The closed kinetic chain (CKC) exercise to the shoulder joint showed higher muscle activity in most muscles for the SMVG, and statistically significant differences in the anterior deltoid (AD), the pectoralis major (PM), and the multifidus (MF) in particular.

Conclusion: The intermediate frequency (50 Hz) string vibration was the effective vibration stimuli for Closed kinetic chain (CKC) exercises.

Keywords: Sling exercise therapy, Vibration ball, Muscle activity, Rehabilitation exercise, Disabled person

INTRODUCTION

Spinal cord disorders involves spasticity, or paresis in the damaged area of spinal cord below it when spinal cord nerve damage or sensory nerve and motor nerve disabilities occur due to a disease or a sudden accident of traffic accidents, sports injuries among others (Le & Price, 1982). 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) as a result of the complex issues in the spinal nerves and sensory nerves (Buffart, van den Berg-Emons, van Wijlen-Hempel, Stam, & Roebroeck, 2008). Also, most spinal disordered people perform motions and movement in daily life by relying on a wheelchair due to their lower limb disabilities. Therefore, 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 (Cruz-Almeida, Martinez-Arizala, & Widerström-Noga, 2005), 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. Many studies on people with spinal cord 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 elastic bands, and functional electrical stimulus through PNF aquatic isokinetic equipment (Grobelnik & Kralj, 1973).

Recent exercise trends have continuously suggested the therapeutic method for improving recovery in terms of active and rehabilitative aspects (Dallmeijer & Van der Woude, 2001), sling exercise therapy and vibration stimulation are attracting attention in these part. 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 in unstable environments. Also, vibratory stimulus has the advantage of additionally improving the functions of the neuromuscular system as a mechanism of the tonic vibration reflex by changing the exercise intensity (low intensity, intermediate intensity, high intensity) through changes in frequency (Hz), amplitude (mm), and magnitude (Nordlund & Thorstensson, 2007; Oh, Kang, Kwon, & Min, 2015; Oh, Kang, Min, & Kwon, 2015).

However, most of the studies on the whole body vibration situation have been conducted and the effect of the muscle activity according to the change of the vibration stimulus is still insufficient.

Therefore, the purpose of this study is to compare and analyze the effective muscle activity of the upper body through the provision of various frequency (low intensity (30 Hz), mid intensity (50 Hz), high intensity (70 Hz)) of sonic vibration during the sling exercise therapy.

METHODS

1. Participants

Fifteen male in their 40s and 50s, with lower limb disabilities with no history of particular medical diseases were recruited for this study. The subjects participating in the study underwent closed kinetic chain (CKC) exercises through sling exercise therapy and were randomly divided into a sling exercise group (SG n=4), a sling with low frequency (30 Hz) vibration group (SLVG n=4), a sling with mid-frequency (50 Hz) vibration group (SMVG n=4), and a sling with high frequency (70 Hz) group (SHVG n=4) in accordance with the type of sling exercise and vibration balls. 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 Committee (IRB) at CBNU.

Table 1. Characteristics of the subject

Group	N	Age (yr) M ± SD	Weight (kg) M ± SD	Height (cm) M ± SD
SG	4	40.2±2.5	65.9±9.3	172.8±5.2
SLVG	4	40.3±1.8	66.7±8.2	170.5±3.5
SMVG	4	41.2±2.3	68.5±5.6	173.5±2.5
SHVG	4	42.1±1.9	64.9±2.8	169.8±2.6

2. Procedure

The experiment processes showing the changes in muscle activity by part in accordance with the sling exercise and the vibration balls intensity provided are indicated in (Figure 1). Also, demand for target muscles was investigated by measuring reference voluntary contraction (RVC) and by distinguishing muscles with a high frequency of use during the use of a wheelchair before doing sling exercises.

The exercise method was performed into closed kinetic chain (CKC), 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. The sling exercise method is presented in (Figure 2). Usually, the CKC is carried out with the distal segment of the body at a fixed position, and because it is capable of simultaneous contraction of the agonist muscles, the antagonist muscles, and the synergic muscles due to its multi-joint form, it provided much help during rehabilitation exercise and training. The Motion involves shoulder joint flexion and extension at the supine position by using a sling cord. The exercise method consisted of two type of muscle contraction. Isometric exercise was conducted three times for five sec at the peak of maximum contraction, while isotonic exercise was performed in three sets of twelve reps in two seconds with one second of concentric contraction and once second of eccentric contraction, with the consequent muscle activity being recorded. Furthermore, the resting time between each set was 30 seconds, with the number of reps and sets determined by considering fatigue in. The vibration stimulus provided during sling exercise is presented in (Figure 3).

The provided vibration frequency is divided into low (30 Hz), mid (50 Hz), and high (70 Hz) according to the stage set in the vibration ball. The vibration stimulation was provided by a sonic vibrator. EMG device was used by using noraxon wireless system. 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), biceps (BC), and the multifidus (MF). EMG signals were amplified, bandpass filtered (passband 20~140 Hz), notch-filtered at 60 Hz, and then sampled at 1,000 Hz.

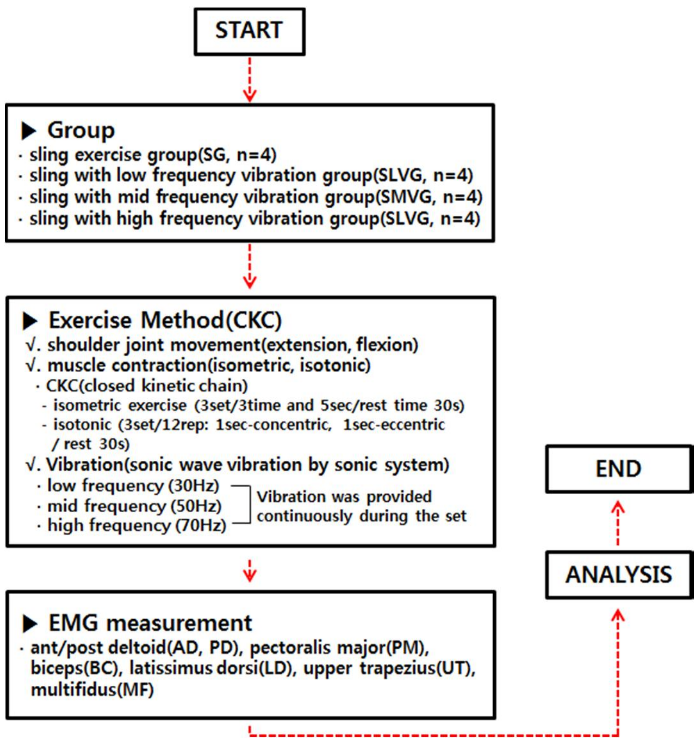

Figure 1. Block diagram of experimental procedure.

3. Data analysis

To confirm statistical significance, the mean and standard deviation of the muscle activity results were calculated. And, sling exercise with

Figure 2. Closed kinetic chain (CKC) exercise method isometric/isotonic contraction in shoulder joint.

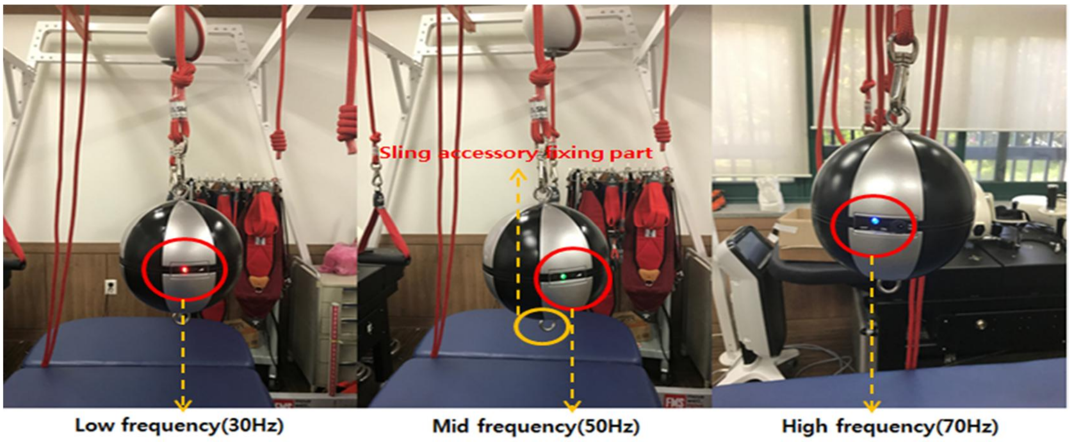

Figure 3. Vibration ball of sonic system (frequency, Hz).

vibration stimulus of each group by using the spss 18.0 Korea. 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 $p<.05$.

RESULTS

The results of isometric and isotonic contraction during the flexion and extension of the shoulder joints are presented in (Table 2).

During isometric flexion, the muscle activity of most muscles was high for the SMVG, with the anterior deltoid (AD), pectoralis major (PM) displaying statistically significant differences in (Figure 4). Also, the iso-

Table 2. The result of EMG measurement value in CKC exercise (unit: % RVC), M ± SD

Exercise form	Muscle	Group				$p<.05$	*F*	Bonferroni
		SG (n=4)	SLVG (n=4)	SMVG (n=4)	SHVG (n=4)			
Isometric flexion	AD	64.0±13.5	84.8±7.1	91.2±5.2	81.7±7.9	.002*	4.065	SG<SMVG
	PM	36.1±14.9	44.2±15.3	51.5±15.3	47.0±16.7	.026*	2.257	SG<SMVG
	UT	57.5±17.9	66.1±15.1	78.6±13.7	71.1±14.6	.458	.860	
	BC	19.6±6.8	20.9±5.1	22.6±8.9	22.8±6.5	.363	.807	
Isotonic flexion	AD	68.8±14.4	82.0±13.7	90.0±7.7	85.6±12.7	.006*	1.130	SG<SMVG
	PM	31.2±11.9	32.3±10.7	38.8±9.2	31.5±8.3	.259	2.179	
	UT	68.9±15.7	76.8±15.8	80.7±10.4	76.5±14.7	.463	.164	
	BC	14.9±8.8	17.3±12.3	22.4±6.0	22.4±13.0	.568	1.707	
Isometric extension	PD	38.9±11.2	36.4±16.2	43.6±12.5	38.6±18.5	.750	.486	
	LD	39.5±16.4	42.6±9.2	49.8±5.7	44.0±12.9	.629	1.615	
	MF	52.8±25.7	68.3±7.8	79.5±13.0	70.3±23.2	.009*	4.117	SG<SMVG
Isometric extension	PD	42.1±20.5	43.6±24.1	53.0±27.7	48.7±22.7	.819	.614	
	LD	48.0±21.9	50.4±23.4	57.9±29.7	52.7±21.8	.763	.461	
	MF	69.8±18.1	74.7±12.2	78.8±10.3	77.7±11.1	.998	.208	

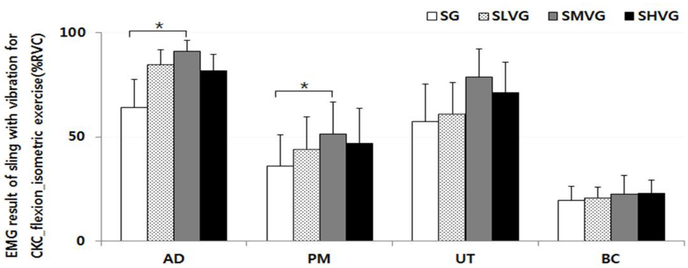

Figure 4. The result of EMG measurement in CKC isometric flexion exercise. *$p<.05$: significantly different between the group

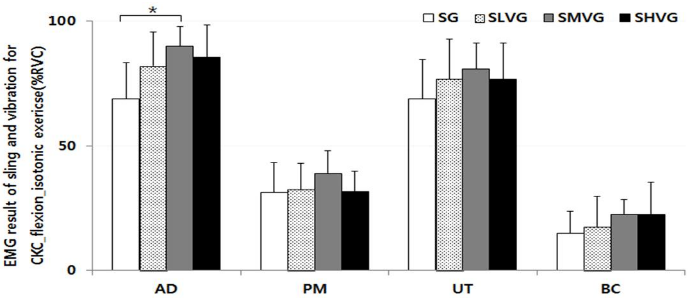

Figure 5. The result of EMG measurement in CKC isotonic flexion exercise. *$p<.05$: significantly different between the group

tonic flexion was high for the SMVG. There was no statistically significant different except for the AD. And, the results are shown in (Figure 5).

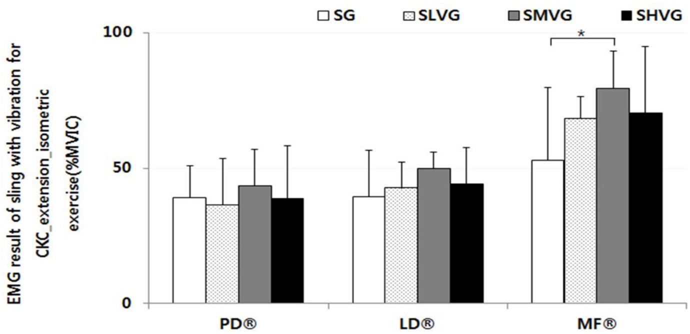

Figure 6. The result of EMG measurement in CKC isometric extension exercise. *$p<.05$: significantly different between the group. PD: posterior deltoid / LD: latissimus dorsi / MF: multifidus

Shoulder joint extension, the muscle activity of most muscles was high for the SMVG, with the multifidus (MF) displaying statistically significant differences in (Figure 6). The isotonic contraction of shoulder extension, the most of the muscles showed high muscle activity, but there no statistically significant difference.

DISCUSSION

Most people of spinal cord injuries live their daily life by depending on a wheelchair and display, in complexity, damage to their nervous and motor systems. The sling, which is a method that can fulfill such a demand, can be applied as a rehabilitation 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 encourages the patients themselves to participate in active therapy, it can be an effective device for relaxation exercises, joint range of motion improvement, sensory integration training, and muscle strength (Kirkesola, 2009). Furthermore, vibration increases the gravitational load on the neuromuscular system as in muscle strength training by increasing acceleration. 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 (Marco Cardinale & Bosco, 2003).

The results of the flexion exercises show that most muscles during isometric and isotonic contraction display a higher muscle activity in the SMVG group. Especially, there was a statistically significant higher in the AD and the PD muscle. Also, the muscle activity of the PD, the LD, and the MF was higher in the SMVG than the other groups during the isometric and isotonic contractions of shoulder joint extension. During the comparison between SG and the other groups, the MF displayed statistically significant higher in the SMVG during isometric contraction. Furthermore, most disabled people suffer from areas that are incapable of receiving the feeling of muscle contractions due to paralysis of the nerves of the spine. In particular, 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. The results of the study determine that sling exercise and vibrations sufficiently perform the role rehabilitation exercise in that they display statistically significant higher in muscle activity and particular vibration stimulus. A previous study (Rittweger, Mutschelknauss, & Felsenberg, 2003) on the chronic effectiveness of vibration provisions found improvements in muscle activity and muscle strength due to the vibration stimulus of 30~50 Hz.

These results support the argument of the present study. Slings transmit vibration stimulus to the body in the form of string vibration 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. As a result, it is judged that vibration damping phenomenon is rather increased in low intensity stimulus. Also, it is considered that the pattern of vibration stimulation transmission is reduced due to excessive increase of amplitude (mm) in high intensity vibration during sling exercise. As a result, it is considered that the mid vibration frequency provided the efficiency of the nervous system stimulation through the proprioceptor sense.

Therefore, mid-intensity frequency (50 Hz) delivered a more effective stimulus to the body. But, there are limitations of this study. The present study which provides vibration stimulus to the string carries limitations. Also, Disabled people are not familiar with using exercises involving the sling, so they face difficulties performing the accurate motions aiming the target muscles.

CONCLUSION

The purpose of the present study is to provide reliable data by comparing and analyzing the effective muscle activities of the upper body by conducting a variety of vibration stimulation during sling exercise therapy in disabled people. The result of applying CKC exercise found that the muscle activity of most muscles was higher for the SMVG, with the anterior deltoid, the pectoralis major, and the multifidus, in particular, displaying statistically significant differences. However, the study succeeded only in verifying short term effectiveness and was limited in failing to verify an effect through a long-term program.

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