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The Effect of Arm Movements in the during Standing Position on Lower Limb Global Synkinesis and Balance in Stroke Patients

Background: Stroke patients require arm movement exercising for various stimulations in standing position for various stimulations rather than in a sitting position because they require integrated skillful movements, such as stretching, holding, and controlling.
Objective: This study was conducted to provide foundational clinical data about lower limb global synkinesis in stroke patients using arm movements in a standing position.
Design: Randomized controlled trial.
Methods: The subjects were divided into a control group (n = 10) and an experimental group (n = 10), and a pre-test was conducted to evaluate leg global synkinesis (GS) and balance. Intervention method is stretching an arm to hold a ball, repeating supination and pronation of the hand only while maintaining the arm extended as much as possible, repeating shoulder abduction and adduction while holding the pegboard. This was followed by a three-week intervention during which re-measurement was conducted in the same way as was done for the pre-test.
Results: The control group showed a significant difference in GS and balance during plantar flexion ($p<.05$), and the experimental group showed a significant difference in GS and balance during all movements ($p<.05$, $p<.01$, respectively). There was a significant difference in GS and balance between the two groups during dorsiflexion ($p<.05$, $p<.01$, respectively).
Conclusion: The findings demonstrate that human arm movements in a standing position can reduce GS in the affected limb, and balance can be improved by stimulating the surrounding tissues of the affected limb and changing them positively.

Key words: *Balance, Global synkinesis, Standing position, Stroke*

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INTRODUCTION

Stroke is a dysfunction in the central nervous system that continues for more than 24 hours due to cerebrovascular problems, resulting in various disorders depending on the lesion size and location [1]. It is accompanied by an abnormal motor pattern, such as a reduction in motor ability, improper posture, and reduced balance capability, and the lack of weight-bearing capability due to body paralysis on the opposite side of the brain lesion, resulting in losing functional performance of the arms and legs [2]. An abnormal motor pattern in the arms and legs, persistent primitive reflexes, abnormal muscle tone and spasticity, associated reaction, and synergies may occur [3]. In particular, functional disorder in the legs degrade the balance ability of stroke patients, restricting them from participating in social activities. Thus, the recovery of leg functions on the affected side is very important [4].

One clinical characteristic of stroke patients is that when one part of the body contracts, involuntary movements occur on the opposite side [5]. This movement occurs in the homologous muscle on the affected side during muscle contraction on the unaffected side. In particular, this movement is easily observed during intense contraction or while performing difficult tasks [6]. This phenomenon is variably called global synkinesis (GS), mirror movement, and motor overflow [7], these terms are also used in patients with other neurological disorders, such as schizophrenia, Huntington's disease, and Parkinson's disease [8]. The reason for using so many terms for the same clinical symptoms exhibited in patients with neurological impairment is due to the lack of definite criteria about diverse involuntary muscle activities and confusion about classification combined with other motor concepts that display similar phenomena [9]. However, Boissy et al. [7], defined the excessive contraction exhibited in stroke patients during task execution as GS. GS is displayed along the transcallosal pathways and immature myelin, and it clearly occurs in joints intruded by neurological impairment [10]. As described above, since stroke patients with neurological impairment have changes in GS based on the degree of motor damage on the affected side [7], a number of studies have employed GS as an evaluation index to determine the recovery pattern after applying exercise methods to stroke patients [11].

Although stroke patients have limitations of various physical body functions rather than one functional limitation, current clinical therapeutic approaches to recover their body functions only focus on one element during treatment [12]. For stroke patients, the purpose of therapeutic exercise is to return to daily living activities, such as bathing, changing clothes, and eating, as quickly as possible. To accomplish these tasks, skillful movements, such as posture control, movement ability, stretching, holding, and handling in a standing position, should be performed in an integrated manner [13]. Thus, exercising in a standing position rather than a sitting or lying position can improve a patient's predictive postural control abilities, such as maintaining body posture and shifting one's weight for various stimulations [14]. Accordingly, the need to exercise in a standing position has been suggested as an approach for therapeutic exercises for stroke patients [13, 14].

The primary purpose of therapeutic exercise for stroke patients is to enable them to participate in social activities and be more independent [15]. To accomplish those goals, it is essentially necessary for stroke patients to learn how to control their posture automatically by applying exercise methods that require various complex movements, rather than simple movements. Global synkinesis needs to be assessed to further elucidate the motor effects in a standing position in stroke patients. Thus, this study aims to identify the difference in changes in the leg GS and balance of stroke patients by performing arm movements in a standing position by applying various movements, thereby providing a foundation of clinical data regarding the recovery level of leg functions in patients through automatic postural control using arm exercises in a standing position in the future.

SUBJECTS AND METHODS

Subjects

This study was approved by the institutional bioethics committee (SH-IRB 2018-13). Twenty patients who were admitted to J Hospital in Jeollanam-do from October to November in 2018 were selected as the study subjects. The selection criteria of the subjects were as follows: those who were diagnosed with hemiplegia recently, one to two years

Table 1. Characteristics of subjects

Variable	Control group (n=10)	Experimental group (n=10)	P
Age (years)	46.11±4.22	48.12±3.24	.621
Height (cm)	168.52±2.41	171.43±4.34	.452
Weight (kg)	69.31±6.91	70.21±6.58	.245
Stroke duration (month)	14.81±1.34	16.16±2.41	.645
Paralyzed side (Rt/Lt)	9/1	8/2	
MMSE-K (score)	25.12±1.25	25.61±1.51	0.348

MMSE-K: mini-mental state examination—Korean version
$p<.05$

from the onset date, those with no other neurological or orthopedic medical history, those who have no visual deficiency or unilateral neglect, those who had a modified Ashworth scale (MAS) between G_{I} and G_{II}, those who could stand for more than 30 min. without assistance, those who could walk 10 m with or without a cane, those who scored more than 24 points in the mini-mental state examination-Korea version (MMSE-K) so they could understand and follow the instructions of the researchers, and those who understood the purpose of the study and participated in this study voluntarily. The general characteristics of the subjects are presented in Table 1.

Intervention

The subjects in the control group participated in an arm exercise in a standing position after aligning the handle height to the iliac crest the patients for utilizing the height-adjustable electronic arm exercise tool (GM-3000, South Korea).

The experimental group participated in an arm exercise after aligning a height-adjustable electronic table with the iliac crest height of the patients as follows: stretching an arm to hold a ball and transferring the ball to the fixed basket, repeating hand supination after extending the arm as much as possible, repeating supination and pronation of the hand only while maintaining the arm extended as much as possible, repeating shoulder abduction and adduction while holding the ball, and inserting and pulling a peg to and from the pegboard [12], and all group intervention programs were applied once a day (30min), four times a week for three weeks.

Measurement Methods

Measurement of the Berg balance scale

The Korean version of the Berg balance scale (BBS) is a tool used to assess the balance ability of hemiplegic patients due to brain diseases. The scale consists of 14 items related to applied activities of daily living. Each of the items is rated on a five-point scale from zero to four; zero is the lowest functional level and four is the highest functional level. A perfect score is 56 points. The higher a person's score, the better his/her balance ability. Its test-retest reliability is r = .98, and interobserver reliability is r = .98 [16]. The mean value after measuring three times was used as the result value.

Measurement of the Global synkinesis of the leg

To measure the GS level, the surface electromyography (EMG) MP 100 system (Biopac Systems, USA) was employed. The hair on the skin was shaved, and a portion of the skin was completely cleansed with alcohol before attaching the electrodes to minimize the skin resistance. The recording electrodes were attached to the medial gastrocnemius and tibialis anterior muscle flaps, and the ground electrodes were attached to a nearby portion of the skin without disturbing the exercise. Surface electrodes (Desys Inc., DE-2.1 single differential electrode, USA) were used for the recording electrodes. To acquire the surface EMG signals, a sampling rate was set to 1,000 Hz, and the filter was set to 20 Hz to 450 Hz. To store and analyze the EMG signals, the EMG MP100 (Biopac Systems) program was used. The subjects were comfortably seated in a chair, and the maximum contraction was applied at a 90° angle while the subjects participated in two exercise tasks (dorsiflexion and plantar flexion) on the unaffected side. The knee joint was maintained at a 90° angle. To prevent compensation, the trunk, opposite hip joint, knee joint, and ankle joint were fixed, and then stabilized for 5 sec. This was followed by maximum contraction for 10 sec., which represented one set. The subjects rested for 10 sec. between sets, and a total of three sets were conducted. The GS level was calculated as a root mean square value of EMG [17].

Data analysis

Data were processed using Window SPSS 20.0 software. The subjects' general characteristics and normality were analyzed using the Shapiro-Wilk test. The paired t-test was used to investigate leg GS and BBS within each group. Intergroup differences for leg GS and BBS were analyzed using analysis of covariance (ANCOVA), and statistical significance was set at α=.05.

RESULTS

1. Comparison of changes in leg GS and balance within the two groups

The analysis of leg GS and balance in the control group showed that there was no significant difference in GS during dorsiflexion, but there was a decresed significant in GS during plantar flexion ($p<.05$) (Table 2). Also, increased significant difference in balance was found ($p<.05$) (Table 2). And the analysis of leg GS and balance in the experimental group showed that there was a decreased significant difference in all variable ($p<.05$) ($p<.01$) (Table 2).

Table 2. Comparisons of changes in GS and BBS for within group.

Variable		Group	Pre-test	Post-test	t	p
GS (Hz)	Dorsi flexion	C-group	0.047±0.022	0.046±0.016	1.489	.171
		E-group	0.046±0.021	0.042±0.033	3.016	.015*
	Plantar flexion	C-group	0.044±0.018	0.043±0.012	2.571	.03*
		E-group	0.044±0.019	0.042±0.017	2.739	.023*
BBS(score)		C-group	42.4±1.65	44.2±1.87	-2.29	.048*
		E-group	43±2.31	49.1±4.07	-4.103	.003**

*p<.05 ,**p<.01
C-group; Control group, E-group; Experimental group
GS; Global synkinesis, BBS; Berg balance scale

Table 3. Comparison of changes in GS and BBS for between groups.

Variable		Group	Pre-test	Post-test	F	p
GS (Hz)	Dorsi flexion	C-group	0.047±0.022	0.046±0.016	8.42	.01*
		E-group	0.046±0.021	0.042±0.033		
	Plantar flexion	C-group	0.044±0.018	0.043±0.012	3.362	.084
		E-group	0.044±0.019	0.042±0.017		
BBS(score)		C-group	42.4±1.65	44.2±1.87	11.063	.004**
		E-group	43±2.31	49.1±4.07		

*p<.05 ,**p<.01
C-group; Control group, E-group; Experimental group
GS; Global synkinesis, BBS; Berg balance scale

2. Comparison of changes in leg GS and balance between the two groups

The analysis of leg GS and balance between the two groups showed that there was a significant difference in GS during dorsiflexion (p<.05) (Table 3), but no significant difference was found in GS during plantar flexion. However, there was a significant difference in balance between the groups (p<.01) (Table 3).

DISCUSSION

Stoke patients have various posture control problems in a standing position because they experience a very large range of postural sway and biased weight support in the leg on the unaffected side in comparison to people who have not had a stroke; moreover, stroke patients experience selective muscle control failure, such as a reduction in the ability to move their center of gravity, resulting in reduced balance ability [18]. The loss of muscle control function is followed by changes in GS, which is related to abnormal muscle contraction [19]. GS is a typical symptom in stroke patients due to impairment in the central nervous system. Changes in GS have been reported after applying a functional recovery exercise [20]. An increase in GS in the arms of stroke patients implies a functional recovery in those limbs, whereas the reduction in GS in the legs represents improvement in the functional ability of those limbs [5]. Thus, the functional recovery level of patients, as determined by applying exercises, can be evaluated by determining changes in GS [7]. As an approach to exercises for functional recovery of stroke patients, exercising in a standing position has more positive effects on the body than exercising in a sitting or lying position [21]. In particular, arm exercises in a standing position could improve the functional abilities in the affected leg in addition to the arm effect on the affected side, helping improve the balance of patients, which is predictive of postural control ability [13].

In the present study, the subjects were divided into control and experimental groups, and arm exercises were conducted in both groups. The results demonstrated that the control group had a significant decrease in GS during dorsiflexion; however, a significant difference in GS was not found during plantar flexion although the mean values decreased, indicating a significant difference would occur if the period of exercise was increased in the future. In the experimental group, a significant decrease in GS was found during both dorsiflexion and plantar flexion; a significant increase in balance was found in both groups. Thus, the level of GS is related to muscle contraction and action potential in the central nervous system.

A previous study reported that muscle contraction and central nervous system excitability increased as the change in GS increased [5]. However, it was reported that it is necessary to reduce GS for functional recovery in legs [22]. The reason for this was because, in stroke patients, the brain perceives arm movements as a single unit and as a coordinated single motion, which is why GS should be increased in arms [23]. In contrast, the brain perceives leg movements as an alternate movement so that an increase in GS acts as a functional obstacle factor, which is why GS should be decreased in the legs [22, 24]. The present study derived the same results that were reported in previous studies.

Stroke patients should be able to perform various tasks simultaneously to resume their normal daily living activities. Although improvements in balance are important in terms of performing various tasks, training for patients should consist of a single task form of exercise or a simple form of exercise [25]. Since applying those training methods takes a significant amount of time and substantially decreases the automatic postural control ability of patients, arm training in a standing position, which can improve automatic postural control under various circumstances, should be performed to overcome the shortcomings of previous training methods [26]. However, a previous study reported that if the purpose of the task execution during arm training was presented to subjects, instead of performing general arm training, such as arm stretches in a standing position, it could improve the dynamic efficiency of the motor nerves because the muscle contraction and movements of legs can be increased in patients, enabling them to execute tasks in a standing position [27].

In a study that used training of repetitive arm stretching in a standing position for stroke patients based on the above result, the muscle strength in the legs of stroke patients improved [14]. In a study that used task performance training in a standing position, when applying task execution with goals during an arm exercise rather than general arm stretch training, the leg functions of stroke patients improved, including their ability to shift their weight control in the direction of their movements [12]. Another previous study reported that applying arm exercises with goals in a standing position was an effective exercise method that could improve the balance ability of stroke patients because it had a positive impact on the muscle strength of the leg on the patients affected side [26]. The present study also found that when applying task training with goals in a standing position rather than performing general arm training without goals, the experimental group had a significant decrease in changes in GS during dorsiflexion and a significant increase in balance, indicating that arm training that applied task execution in a standing position results in a greater decrease in leg GS, thereby effectively increasing the subjects balance ability. This result implies that the execution of arm tasks, such as external stimulation, for stroke patients in a standing position is effective when applying a weight support to the leg on the affected side [28], thereby further stimulating the proprioceptive function around the joint and muscle contraction around the leg on the affected side [29]. This resulted in a positive change in the afferent information delivered to the central nervous system. Thus, arm training that applies task executions in a standing position effectively reduced GS. Abnormal muscle contraction in the leg on the affected side was decreased, increasing the subjects balance ability, thereby further improving the predictive postural control ability of stroke patients using arm training that applied task executions rather than performing general arm exercises.

CONCLUSION

This study reported a reduction in leg GS on the affected side and improvements in balance by applying arm training in a standing position rather than a simple form of exercise for rapid recovery of stroke patients. In particular, arm training that applied task executions in a standing position further stimulated the tissues around the leg on the affected side, which resulted in positive changes, indicating that the exercise method could reduce GS in the leg and more effectively improve balance in stroke patients. Thus, it is necessary to perform various evaluations on the leg functions of stroke patients by applying a variety of arm training programs in a standing position to support rapid recovery of stroke patients so they can return to their normal activities of daily living.

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