



Original Article

Effects of upper extremity training in a standing position on trunk alignment in stroke patients

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Abstract. [Purpose] This study aimed to examine the effect of upper extremity training in the standing position on trunk alignment of patients with stroke. [Subjects and Methods] Twelve stroke patients were enrolled in the study and divided into two groups: a group of six patients in a sitting position and a group of six patients in a standing position. Upper extremity training for 30 min per day, five times a week for six weeks was given to subjects in both groups. In order to assess trunk alignment, lumbar lordosis and thoracic kyphosis were examined before and after upper extremity training using Formetric 4D. [Results] After training the standing position group had no significant change in lumbar lordosis but a significant change in thoracic kyphosis. The sitting position group showed no significant changes in either lumbar lordosis or thoracic kyphosis. The comparison between groups showed there was no significant difference in the change in lumbar lordosis but there was a significant difference in the change in thoracic kyphosis. [Conclusion] Examination of trunk alignment showed that upper extremity training conducted in a standing position reduced thoracic kyphosis more than in a sitting position.

Key words: Alignment, Lordosis, Kyphosis

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INTRODUCTION

Stroke is the most common cerebrovascular disease and the most frequent cause of death as a single disease despite advancements in modern medical technology and increased awareness. Activities of daily living are limited by the disability in sensory, motor, and cognitive and emotional control functions seen following a stroke¹⁾. Due to muscular stiffness and weakness, stroke patients have difficulties in supporting their weight on the lower extremity on the affected side, thereby causing disabilities in balance control while standing, which affects quality of life negatively²⁾. In addition, significant reductions in the function of the upper extremity on the affected side are experienced by stroke, resulting in significant difficulties in independent movements and performing the activities of daily living³⁾.

During arm stretching movements by stroke patients, muscle activity is reduced more in the affected side than in the unaffected side, leading to problems with postural adjustment due to the weakness of trunk muscles⁴⁾. As static and dynamic balance abilities that can maintain the body's center of gravity within the basal plane in the standing position are reduced, asymmetrical posture of the trunk is revealed in order to compensate for the instability. The imbalance in postural control leads to asymmetry in the trunk muscles. The trunk muscles are involved with trunk movements and spinal stability⁵⁾ and extend in a wide area in both vertical and horizontal directions. They also adjust trunk motions in various spatial directions⁶⁾ and are involved with postural control by maintaining balance through maintaining a normal lumbar curvature⁷⁾. It is important for stroke patients to receive training for postural control. Upper extremity training in the standing position improves postural control while maintaining the body's center of gravity⁸⁾. Trainings of the maintenance of a standing position and upper

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extremity are more beneficial to the performances of activities of daily living if they are conducted simultaneously rather than independently⁹). Task training in the standing position can improve postural control thereby helping stroke patients to pay more attention to their safety in complex environments as well as maintaining safety while improving their ability to perform various activities of daily living¹⁰). In addition, standing and dynamic postures are closely related with gait velocity. Functional and dynamic balance training is important to improve the gait and functional balance of stroke patients¹¹).

Trunk alignment is affected by weakness in trunk muscles and abnormal postures following a stroke. Abnormal trunk alignment consequently negatively affects postural control. Therefore, this study aimed to identify the effect of upper extremity training in a standing position on trunk alignment and provide a scientific foundations for upper extremity training in a standing position, which is frequently used clinically.

SUBJECTS AND METHODS

This study conducted experiments with 12 stroke patients who were admitted to Rehabilitation Hospital in Incheon Gyeonggi-do in Korea. The subjects were divided into two groups: sitting and standing groups. The sitting group had four males and two females patients, while the standing group had three males and three females patients. The mean was 62 years for the sitting group and 60 years for the standing group. The mean duration of disease was 13 months for sitting group and 15 months for standing group. The numbers of subjects with right and left hemiplegia were seven and five respectively. Signed consent was given voluntarily by the subjects involved in the study. The experiments were conducted in accordance with the Declaration of Helsinki. The selection criteria for subjects: were hemiplegic patients, moderate severity according to the Fugl-Meyer upper extremity test, and being able to maintain a standing position without assistance for five min or longer. This study was conducted from March 31, 2015 to May 30, 2015. Upper extremity training in either a sitting or a standing positions was given for 30 min per day, five times a week, for six weeks. Upper extremity training involved the following: grabbing a cone on the table and moving it to a specified place, moving a cone on a table to a shelf, stretching an upper extremity to grab a ball to put it into a basket, and stretching an upper extremity to grab a ring and put it onto bar.

This study evaluated postural alignment before and after the upper extremity training between sitting control group and standing experimental group. Postural alignment evaluation was performed using the Formetric 4D system (DIERS, International GmbH, Schlangenbad, Germany, 2010), which provides an alternative to radiographic examination for the analysis of spinal alignment. The Formetric 4D system provides a high reproducibility rate and objective data, as well as accurate analysis on spinal curvature. It can analyze the ear surface of the trunk in three dimensions and examine spinal shapes rapidly using surface contour lines without the need for radiation exposure. The measurement principle is as follows: the surface of the back is reconstructed via raster lines, followed by camera capture thereby locating the estimated spinous process, in order to measure the curvature through anatomical markers and the spinous processes. It can also reconstruct the spinal center line. Through the above method, thoracic kyphosis and lumbar lordosis angles could be read on the images.

The study data were processed using SPSS version 18. The normal distribution of data was demonstrated using the Kolmogorov-Smirnov test. To compare changes in measured variables before and after the upper extremity training in both groups, the paired t-test was used. The independent t-test was used to compare changes in outcome measures between the two groups. The significance level was set at $p < 0.05$.

RESULTS

No significant changes in lordosis or kyphosis were seen in the results of the sitting group, before and after the upper extremity training ($p > 0.05$). In the standing group, no significant changes in lumbar lordosis was found ($p > 0.05$) but significant change in thoracic kyphosis was found ($p < 0.05$) (Table 1). No significant difference in the change before and after the upper extremity training in lumbar lordosis was found between the two groups ($p < 0.05$) but a significant difference in the change in thoracic kyphosis after training was found between the two groups ($p < 0.05$) (Table 1).

DISCUSSION

This study aimed to examine the effect of upper extremity training in sitting and standing positions on the trunk alignment of stroke patients. The result showed that the standing group had no significant change in lumbar lordosis ($p > 0.05$) but

Table 1. Comparison of change in lordosis and kyphosis within and between groups

	Sitting group (n=6)		Post-Pre	Standing group (n=6)		
	Pre	Post		Pre	Post	Post-Pre
Lordosis (°)	30.9 ± 9.5	30.7 ± 7.9	-0.2 ± 2.1	29.8 ± 10.8	30.2 ± 8.5	0.3 ± 2.9
Kyphosis (°)	47.0 ± 6.2	47.9 ± 7.2	0.9 ± 1.3	56.6 ± 5.3	52.2 ± 4.9*	-4.4 ± 2.4#

Values are mean ± standard deviation (SD), * $p < 0.05$: paired t-test, # $p < 0.05$: independent t-test

significantly improved thoracic kyphosis ($p < 0.05$). On the other hand, the sitting group had no significant changes before and after the intervention in lumbar lordosis or thoracic kyphosis ($p > 0.05$). The comparison between the sitting and standing position groups showed that there was no significant difference in the change lumbar lordosis ($p > 0.05$) but had a significant difference in the change in thoracic kyphosis ($p < 0.05$).

The asymmetrical posture of stroke patients in the median plane causes unstable posture. However, balance training in the standing position can help normal weight distribution and recover of a symmetrical posture¹²). The static standing posture can also help the recover of asymmetrically affected trunk muscles and reduce thoracic kyphosis. The trunk muscles necessary for postural control are activated by the reduction in thoracic kyphosis, thereby having an effect on trunk control and balance adjustment¹³). Activities of daily living are negatively affected by hyperkyphosis, significantly degrading quality of life. Twenty to forty percent of the elderly population is affected by hyperkyphosis, and it is closely related with aging. In addition, it can slow gait, reduce balance, cause trunk shaking, and increase risk of falls¹⁴). An increase in thoracic kyphosis is characterized by a bending posture and center of gravity of the trunk moving in front of body, as well as affecting alignment of the joint of the lower extremity. Thus, difficulties in accurate postural control due to reduced reaction to postural sway and the normal gait pattern is reduced due to the disability in postural control can be caused by hyperkyphosis. The bending posture due to hyperkyphosis can increase risk of falls and is one of the main risk factors fall due to the disability in postural control, especially while walking¹⁵).

It is important to improve balance during the rehabilitation of stroke patients because it allows the independent performance of activities of daily living. Standing on two legs without postural sway is easy for a healthy persons whereas it can be difficult for stroke patients and may require a long period of rehabilitation to reacquire. The CPO in sitting and standing positions had more regular fluctuations in the standing position than the sitting position and greater balance is required to maintain postural control while standing¹⁶). Thus, a standing position is more effective in balance training for postural control than a sitting position. Results of dual task training for the affected upper extremity side and gait training given to stroke patients in a standing position showed improvements in ability and that long-term rehabilitation was needed¹⁷). The present results showed greater activation of trunk muscles during upper extremity training in the standing position thereby reducing thoracic kyphosis.

Stroke patients may experience many falls while walking. However, upper extremity training in a standing position can reduce the risk of falls by decreasing hyperkyphosis, demonstrating that rehabilitation in the standing rather than sitting position is more beneficial. During forward stretching movements of the upper extremity by stroke patients, trunk muscle activation differed between both sides and disabilities in anticipatory postural adjustments occurred due to the weakening of trunk muscles on the affected side. Disabilities in feedforward movement adjustments such as anticipatory postural adjustments, lead to patients not being able to cope with unexpected trunk swaying due to the weakening of trunk muscles. Upper extremity training can also provide training for anticipatory postural adjustments and improve the ability to perform activities of daily living¹⁸). Heads of stroke patients is typically positioned more forwardly and it emphasizes a postures with round shoulders and thoracic kyphosis while sitting affecting trunk alignment. However, a standing position can maintain the body's center of gravity in a vertical direction and increase changes in the nervous system and muscle strength in trunk, thereby improving muscle strength and balance¹⁹). The present study result showed that upper extremity training in a standing position had a greater effect on trunk alignment by reducing thoracic kyphosis than training in a sitting position. Upper extremity training in a standing position strengthened trunk muscles while maintaining the body's center of gravity in a vertical direction and activated trunk muscles during upper extremity training thereby improving postural adjustment due to the effect on trunk alignment. Furthermore, it can help independent daily living through anticipatory postural adjustments as well as reducing the risk of fall.

The limitations of this study were the small number of subjects and no comparison of changes in scoliosis because of the focus only on lumbar lordosis and thoracic kyphosis-related variables when examining trunk alignment. In the future, comparison of changes in scoliosis as well as trunk alignment and balance will be needed.

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