The Effect of Upper Extremity Training with a Focus on Functional Reaching, on Trunk Control and ADL Performance in Post-Stroke Hemiplegic Patients

The Journal of Korean Society of Physical Therapy

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Purpose: In this study, we tried to determine the effect of upper extremity training such as functional reaching onimproved trunk control and ADL performance in post-stroke hemiplegic patients.

Methods: We randomly selected 11 stroke patients in the hospital, who had a problem with the upper extremity, trunk and ADL performance. The patients were divided into the conservative training group and the functional reaching training group. We applied general occupational therapy only in the conservative training group whereas we applied upper extremity training with a focus on functional reaching in the functional reaching training group. To compare the two groups we used several assessment tools such as Modified Barthel Index (MBI), total Trunk Impairment Scale (TIS), static TIS, dynamic TIS and coordinative TIS.

Results: The results obtained were as follows: (1) In the functional reaching training group, there was a statistically significant difference in the total TIS score, dynamic TIS score, and MBI. (2) We compared the results obtained before training with the changes in the results obtained after training and found that there was a relation between the assessment outcomes. Especially, static TIS score showed a relation in both groups.

Conclusion: Functional reaching training influenced both the trunk control and ADL performance. Especially, the functional reaching training group demonstrated better static trunk control ability than the conservative treatment group.

Key words: Stroke, Functional reaching, Trunk control, Anticipatory Postural Adjustments, ADL performance

Received: March 17, 2011
Revised: June 01, 2011
Accepted: June 13, 2011
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I. Introduction

Reaching and grasping are basic components related to activities of daily living (ADLs) that require upper extremity movement control.[1] According to Jeannerod[2], reaching and grasping are classified into two distinct components. Reaching, as the mobile component, is to move the hand quickly toward an object to be grasped and grasping, as a component of the cupping procedure, is the opposition of fingers for a precision grip. Thus, reaching and grasping are the prerequisites for controlling muscle force production in the upper extremity (UE) of humans.[3] Selective movement of the UE influences the activity of neuromuscular system in the trunk and lower extremity, since the shoulder joint has the highest degree of freedom for movement amongst every joint in the human body and the stability of the shoulder joint depends on muscle activation.[4] Therefore, it is necessary to prepare the trunk before the movement for ensuring stability of the UE during reaching and to stabilize the position related to extremity movement. These are called anticipatory postural adjustments (APAs).[5] APAs are differentiated from postural reactions occurring when it is difficult to maintain the balance, and APAs as a feedforward system occurprior to movement execution to minimize postural disturbance caused by the movement.[6] APAs in the trunk are the prerequisites for ADLs and motor control in stroke patients, which arerelated to functional improvement on a long-term basis, and are important in evaluating the severity and diagnosis of the impairments.[7]

Hemiplegia resulting from stroke is associated with motor function impairment[8] and is accompanied by difficulties in performing the functional activity.[9] Changes in neuromuscular activity occur in many aspects such as reduction of functional motor units, variation in the recruitment order of motor units, and change in motor unit firing rate.[10] The change in neuromuscular activity alters the ability of agonists to enhance performance of tasks, motor control, and it leads to abnormal movement,[9,11] loss of co-contraction and the ability of antagonists.[12] As a result, stroke patients have difficulties with changing postural set and selective activities.[13] Moreover, hemiplegic patients show weight bearing asymmetry because they have difficulty in transferring their weight to the more affected side as compared to the less affected side. This may limit the use of the lower extremity and neurologic recovery in the more affected side, and hence, weight bearing bias towards the less affected side influences the general body to prevent the normal movement pattern and to limit functional activity.[15]

Previous studies of reaching in hemiplegic patients have reported that APAs of the trunk as well as reaching muscles of the more affected side are impaired.[16] For a better functioning of the UE, ADL training in the sitting or standing position involving the trunk is needed prior to the UE movement such as reaching and grasping.[17] During forward reaching, hemiplegic patients have a limitation of the scapular movement, furthermore, the most mobile joint in humans, the shoulder joint, also has limitation of movement. Normally, there is a large diversity in the range of motion of the scapula. For example, during elevation of the suprahumeral joint to 120 degrees, upward rotation of the scapulothoracic joint to 60 degrees occurs, and it supports the elevation of the UE to a maximal of 180 degrees.[18] However, reduction of antigravity muscle activity and ADL loss in the trunk after neurologic deficit lead to difficulty in the performance of functional tasks like reaching and grasping due to the lack of stability of the proximal part.[19]

Recently, the relationship between trunk control and ADLs has been investigated with the view that postural control of the trunk influences ADLs to a great extent.[20] Franchignoni, Tesio, and Ricupero[21] reported that considering the Functional Independence Measure (FIM) and the Trunk Control Test (TCT) at the same time provides better prediction and explanation of ADL performance ability after discharge rather than evaluating the patients using the FIM scores only. And the newly developed Trunk Impairment Scale (TIS) is widely used for evaluating the trunk function in stroke patients.[22] Fujiwara et al[23] showed high intertester reliability, acceptable content validity, concurrent validity and predictive validity of the TIS. However, there is lack of studies onthe effect of physical factors such as trunk function on the performance of the ADL ability.

Therefore, the present study aimed to investigate the effect of scapular training for mobile stability and functional reaching training combined with rotation movement of the shoulder and grasping task on trunk control and performance of the ADL ability in post-stroke hemiplegic patients.

II. Methods

1. Participants

We studied 11 stroke patients who were inpatients in the 00 rehabilitation center in the Gyonggi Province from April 2008 to May 2008. Initially, patients were randomized by a screening test in a 1:1 ratio to receive conservative training or functional reaching training. The inclusion criteria included: (1) < 1 year after stroke, (2) score of > 21 on the MMSE-K, (3) basic communication ability and (4) obeying the instructions. Pain in the shoulder region was the exclusion criteria. Informed consent was obtained from all participants before the study. All subjectsagreed spontaneously to follow the procedure of this study.

2. Experimental design

In this study, participants were divided into the conservative training group (control group) and the functional reaching training group (experimental group). The control group received conservative occupational therapy. They also received education once to prevent overlapping of the content of treatment and to eliminate preconception regarding the treatment. Conservative occupational therapy included range of motion exercises, strengthening exercises such as progressive resistive exercise, and other interventions commonly used to treat stroke patients, for example, task- oriented training and ADL training. Other interventions were chosen individually based on the decision of the occupational therapist. The experimental group received scapular training for mobile stability and functional reaching training combined with shoulder rotation movement and grasping task in addition to the conservative occupational therapy 5 times a week for 4 weeks (20 times).

For the evaluation of trunk function and ADL performance, we used the TIS. This scale was developed by Verheyden et al.[24] to evaluate the static and dynamic ability for trunk control, and coordination in the sitting position. The TIS consists of three subscales, static sitting balance (static TIS), dynamic sitting balance (dynamic TIS), and trunk coordination (coordinative TIS), and each subscale was sorted into 3, 10, and 4 tasks, a total of 17 tasks. The full scores for these tasks are 7, 10, and 6 respectively. The range of scores is from 0 to 23, and a higher score means better trunk control ability. TIS showed high reliability. Intertester reliability of the subscales was between r=0.66 to r=1.00, and intratester reliability was between r=0.87 to r=0.91. Internal consistency of the test tools was also high (Cronbach's alpha=0.89). Content validity was determined by the similarity with tasks related to the trunk area in the Stroke Impairment Assessment Set and concurrent validity was measured by correlation with TCT (r=0.91). Predictive validity was measured by regression analysis of prediction factors such as age, duration after stroke, and FIM score during inpatient period influencing the mobility and FIM scores after discharge, and the controlled R2 value was between r=0.66 to r=0.75.[23,24] Verheyden et al.[25] also found that the TIS can differentiate the stroke patients from healthy individuals as well.

Performance of ADL was measured by the Modified Barthel Index (MBI) that was designed by Barthel and Mahoney in 1965, and revised by Shah, Vanclay, and Cooper.[26] MBI consists of 10 items on ADL, is graded at 5 levels depending on degree of assistance, and the total score is 100. Comparing with other evaluation tools, MBI provides benefits including convenience of use, high accuracy, consistency, sensitivity, and simplicity of statistical process and that is the reason why MBI is widely used as anindicator of self-care activity and mobility.[27] It demonstrated a high test-retest reliability (r=89), intertester reliability (r=95).[28]

3. Procedures

To evaluate the two groups objectively and without any preconception, participants had to attend an evaluation meeting once before the treatment. During the procedures, one participant in the control group had to be discharged suddenly, thus we had five members remaining in the control group after exclusion of this patient. Treatment protocol in the experimental group was reaching- oriented occupational therapy based on the Eggers's[29] therapeutic approach: (1) scapular training for mobile stability, (2) scapula, rotators, and elbow movement, and (3) forward reaching movement of the hand to perform the task. The details are as follows:

1) Scapular training for mobile stability

- Supine or upright sitting: improvement in the scapular stability and mobility.
- Upright sitting: scapular anterior/upward rotation.
- Latissimus dorsi and movement of the internal/external rotators.

2) Scapula, rotators, and elbow movement

- Using the improved scapular movement, shoulder movement and elbow flexion / extension.
- Rotators and active assisted and active exercises for the elbow.

3) Forward reaching movement of the hand to perform the task

- Including training of the proximal part of the shoulder, grasping task with other related training. If possible, occupational therapy using hand grasping.

4. Data analysis

Analyses were done with SPSS/WIN 12.0. Clinical characteristics of patients were analyzed with descriptive statistics. The effect of the UE training was evaluated by the nonparametric test. Wilcoxon signed-ranked test was used for the trunk function and Mann-Whitney U test for ADL evaluation. $P<0.05$ was considered as the statistically significant level.

III. Results

1. Clinical characteristics of the participants

There were 9 male and 2 female patients in this study. The average age was 56.7 years in the experimental group, and 57.8 years in the control group. One patient was in his 30's, 2 in their 40's, 3 in their 50's, 3 in their 60's, and 2 patients were in their 70's. Regarding for the duration after stroke, 2 patients had a duration of <6 months after stroke, and 9 had a duration between 6 and 12 months after stroke. There were 5 right hemiplegic patients, and 6 left hemiplegic patients. The cause of stroke was cerebral infarction in one of these patients, and cerebral hemorrhage in the remaining 10 patients (Table 1).

Table 1. Clinical characteristics of participants

Variable	Group	Experimental group (n=6)	Control group (n=5)
		Person	Person
Sex	Male	5	4
	Female	1	1
Age (year)	Means age	56.67±14.9	57.80±12.3
Onset	>6	2	0
(month)	>12	4	5
Diagnosis	Rt hemiplegia	4	3
(Rt/Lt)	Lt hemiplegia	2	2
Caution	Infartion	0	1
	Hemorrhage	6	4
Early cognitive test	MMSE	26.50±3.15	28.20±3.03
Early trunk test	TIS	12.33±3.44	12.20±3.27
Early ADL performance test	MBI	75.50±14.76	79.40±12.99

M±SD
TIS: Trunk Impairment Scale
MMSE: Mini Mental State Examination
MBI: Modified Barthel Index

2. Change in the trunk function and ADL performance within groups

1) Change in the trunk function

Improvement in the trunk function was seen from an increase in the TIS score from 12.33 to 15.67 in the experimental group and from 12.20 to 14.80 in the control group. A significant difference was seen in the experimental group only ($p<0.05$) (Table 2). Regarding the TIS subscales, the experimental group showed an increase in each subscale: static TIS score increased from 5.83 to 6.17, dynamic TIS score increased from 4.67 to 6.83, and coordinative TIS score increased from 1.83 to 2.67. In the control group, the static TIS score decreased from 6.40 to 5.40, dynamic TIS score increased from 4.40 to 6.80, and coordinative TIS score increased from 1.40 to 2.60. A statistically significant difference in the dynamic TIS score was seen in the experimental group.

2) Change in the ADL performance

ADL was improved in both groups: the experimental group showed an increase from 75.50 to 82.67; and the control group showed an increase from 79.40 to 83.00. Statistically significant differences were seen in the experimental group ($p<0.05$)

Table 2. Change of trunk function and ADL performance within group

Test	Experimental group (n=6)			Control group (n=5)		
	Pre-test	Post-test	p values	Pre-test	Post-test	p values
Total TIS (point)	12.33±3.44	15.67±3.67	0.02*	12.20±3.27	14.80±4.09	0.07
Static TIS(point)	5.83±0.41	6.17±0.75	0.41	6.40±0.55	5.40±0.89	0.06
Dynamic TIS(point)	4.67±2.73	6.83±2.64	0.03*	4.40±2.88	6.80±3.11	0.07
Coordinative TIS(point)	1.83±0.75	2.67±1.03	0.06	1.40±0.55	2.60±2.07	0.10
MBI (point)	75.50±14.76	82.67±8.96	0.04*	79.40±12.99	83.00±9.72	0.06

M±SD
* $p<0.05$
TIS: Trunk Impairment Scale
MBI: Modified Barthel Index

3. Change in the trunk function and ADL performance between groups

TIS score was measured for evaluating the trunk function. The TIS score increased by 3.33 in the experimental group, and by 2.6 in the control group. Every TIS subscale showed an increase in its score in the experimental group an increase of 0.33 in the static TIS score, an increase of 2.16 in the dynamic TIS score, an increase of 0.83 in the coordinative TIS score. Whereas the control group showed a decrease in the static TIS score (-0.1), and an increase in the dynamic TIS score (2.4) and in the coordinative TIS score (0.7). A statistically significant difference in the static TIS score was seen between groups ($p<0.05$).

ADL was measured by the MBI. ADL was improved in both groups: increased by 7.17 in the experimental group; and by 3.6 in the control group. No significant difference was found between groups (Table 3).

Table 3. Change of trunk function and ADL performance between groups

Group / Test	Experimental group	Control group	t	p
Total TIS (point)	3.33	2.60	0.68	0.44
Static TIS (point)	0.33	-1.00	2.44	0.04*
Dynamic TIS (point)	2.17	2.40	-0.26	0.78
Coordinative TIS (point)	0.83	0.75	-0.49	1.00
MBI (point)	7.17	3.60	0.89	0.41

* $p<0.05$
TIS: Trunk Impairment Scale
MBI: Modified Barthel Index

IV. Discussion

Post-stroke hemiplegic patients have both impaired UE function and control of anticipatory trunk muscle activity.[16] Loss of postural control ability influences the ADL performance such as gait, wearing clothes, and ambulation.[30] Previous study on anticipatory trunk control and improvement in the ADL performance emphasized on the evaluation and treatment of trunk control as a basic predictive factor of the general ADLs.[31] Therefore, we aimed to investigate the effect of UE occupational therapy with a focus on functional reaching and grasping, on the postural control of trunk and ADL performance.

The functions of the hand and UE are grasping and manipulation, object awareness through the somatosensory pathways in the hand, communication and expression using gestures and hand movement, reference frame for postural control helping in postural stability.18 Among these functions, reaching and grasping affect postural control. There are two aspects of postural control, postural stability that helps to keep our body upright against gravity and body schema that perceives the external information and recognizes it appropriately.[32,33] During postural control, the UE and hand may minimize the anticipatory movement and perturbation, or act as a reference frame that supports postural stability.[5] When you reach out your hand forward to grasp an object functionally, you collect visual and cognitive information from the body orientation and environment.[34] During this procedure, each body part such as the eye, head, and neck needs an independent range of motion and selective movement. To provide stability to each body part, the trunk adjusts the posture in advance and it leads to a selective movement of the UE.[35]

UE dysfunction is common among post-stroke hemiplegic patients. According to a report by Copenhagen, 71% of the 551 stroke patients received physical therapy or occupational therapy, 69% of the mild or severe UE dysfunction patients took therapy after admission for functional recovery of the UE.[36] Also, many hemiplegic patients have secondary complications such as shoulder pain, joint contracture, and deformity, and these complications may be an important factor against UE recovery in stroke patients.[35] UE dysfunction in an early stage after stroke alters antigravity muscle activation in the trunk and the participation of muscle during forward reaching.[37] We analyzed the reaching movement in patients in an acute stage after stroke, and they showed excessive recruitment of voluntary muscle activation, change in the muscle firing rate, and delayed onset of muscle contraction during the first several weeks. After a few months, the authors found an improvement in reaching movement, time of onset of muscle contraction, muscle firing rate, and voluntary muscle contraction as compared to that in the acute stage. However, alteration of muscle activity during reaching was still seen, and it is important to understand the change in the muscle activity during recovery after injury.

Dickstein et al.[38] reported that motor impairment in hemiplegic patients reduces the anticipatory muscle activity of latissimus dorsi, external oblique, and rectus abdominals in the more affected side, and it leads to alteration of neuromuscular activity and anatomical location and biomechanical characteristics of antigravity muscles in the trunk and scapula and shoulder joint, and thisresults in failure of functional shoulder movement and excessive shoulder movement.

In our results, a significant difference in the trunk function between the baseline and after all procedures was seen in the experimental group. It means that UE treatment with a focus on functional reaching and grasping changed the biomechanical features of scapula and supported the functional movement due to the improved UE trunk function and contributed to postural stability as a reference frame.[6] A significant change in trunk function was seen between the baseline and after all procedures in the dynamic TIS score of the experimental group. It is possible that facilitated arm movement activated the trunk better and gave a reference frame for perception of body movement and for adjustment to it. Also, the trunk function as per the static TIS score showed a significant difference between groups the experimental group showed better static TIS scores than the control group. Although, the control group showed more changes in the dynamic TIS and coordinative TIS scores than the experimental group, the differences were not statistically significant. These results might be due to the therapeutic concentration on trunk function that was activated prior to the UE movement in the experimental group. Moreover, improvement in trunk stability may influence the dynamic and coordinated trunk control. And in our results, the experimental group showed a significant difference in ADLs. This suggests that better trunk control ability may lead to better ADL performance, and that trunk is one of the most important factors in APAs for balance and ADL performance.[39]

Therefore as per the result of this study, we suggest that trunk control with functional reaching training and grasping task influences ADL performance positively in a clinical setting.

However, this study has some limitations. First, our results cannot be generalized due to the small sample size. Secondly, except for the physical factors, we cannot explain the other variables because we did not consider the diverse aspects that influence ADL.

Author Contributions

Research design: Song BK
Acquisition of data: Song BK
Analysis and interpretation of data: Song BK
Drafting of the manuscript: Song BK
Research supervision: Song BK

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