Task-Specific Training with Trunk Restraint: Its Effect on Reaching Movement Kinematics in Stroke Patients

SALAH A. SAWAN, Ph.D.*; HUSSEIN A. SHAKER, Ph.D.*; EBTESAM M. FAHMY, Ph.D.** and NAGWA I. REHAB, M.Sc.*
The Department of Physical Therapy for Neuromuscular Disorder & Surgery*, Faculty of Physical Therapy, Cairo University and Neurology** Department, Faculty of Medicine, Cairo University

Abstract

Background and Purpose: Hemiparesis is common following stroke. The ability to reach and grasp is a necessary component of many daily life functional tasks, hence reduced upper limb function has an impact on the ability to perform activities of daily living. In hemiparetic patients, the unrestricted and unguided repetition of a motor task may reinforce compensatory movements. Trunk restraint allowed the patients to use joint ranges that were present but not recruited during unrestrained reaching. This study aimed to compare the effect of specific-task training with and without trunk restraint on post-stroke reaching kinematics.

Patients and Methods: Thirty male chronic stroke patients with age ranged between 40-55 years were included in this study. Patients were divided into two equal group (Group I and Group II). The first group (Group I) received reach to grasp training during which compensatory movement of the trunk was prevented by trunk restraint. The second group (Group II) practiced the same task without trunk restraint. Kinematics of reaching and grasping an object placed within arm’s length were recorded before and after training using two-dimensional analysis.

Results: Trunk-restraint group showed a statistically very highly significant decrease in trunk displacement \((p=0.0001)\) and increase in elbow extension voluntary range of motion \((ROM)p=0.0001\) post treatment while group II showed significant increase in trunk displacement \((p=0.02)\) and highly significant decrease in elbow extension \(ROM\) \(p=0.007\) post treatment. Also, there was very highly significant decrease in trunk displacement \((p=0.0001)\) and increase in elbow extension \(ROM\) \(p=0.0002\) in the trunk-restraint group as compared to the second group without trunk-restraint post treatment.

Conclusion: Task-specific training with trunk restraint can be suggested as an effective method in improving reaching kinematics and arm movement quality in patients with impaired arm function post stroke.

Key Words: Stroke – Arm reaching – Grasping – Trunk restraint – Task-specific training and Two-dimensional analysis.

Introduction

STROKE often impairs the ability to reach with the affected upper extremity. Because reaching is a necessary component of many tasks of daily living, survivors experience decreased autonomy and quality of life [1]. Indeed, many studies have documented the presence of impaired reaching ability and inefficient compensatory movement after stroke [2].

Difficulty extending the elbow after stroke is common and this limitation is clinically observed as part of a flexor synergy pattern that produces concurrent flexion motions, and which also often impairs the survivor of stroke’s ability to control individual joints. Zackowski et al., [3] characterized the difficulty in extending the elbow as part of a “joint individuation deficit”, and hypothesized that this deficit was more correlated with abnormal reaching performance than other potential predictors such as impaired sensation.

In order to compensate the upper limb impairment, participants with hemiparesis can use alternative strategies to improve functional arm and hand use. For example, when the active range of arm motion \(ROM\) is decreased, individuals can transport the hand to the object by using the trunk [4]. This increased trunk recruitment is a compensatory mechanism by which the central nervous system (CNS) may extend the reach of the arm when the control of the active range of the arm joints is limited [8].

A functional quantitative analysis of upper limb movement during arm reaching illustrated that patients with hemiparesis used more trunk flexion and shoulder abduction to compensate for reduced elbow extension and demonstrated
abnormal shoulder abductor power to compensate for reduced shoulder flexor power. These compensatory movement strategies are evident during unilateral upper limb tasks [6].

The compensatory involvement of the trunk is greater for patients with more severe motor deficits [4] and may be related to impairments of grasping [7]. The presence of excessive trunk movement in hemiparetic individuals while reaching may limit the potential recovery of normal arm movement patterns [8]. However, limiting trunk motion in patients after stroke has been shown to encourage more normal elbow and shoulder motion during reach to grasp objects [8].

No studies have been conducted to investigate the effect of trunk restraint on reaching movement in chronic stroke patients in Egypt. This study was designed to investigate the effect of task-specific training with trunk restraint on reaching kinematics in stroke patients.

Patients and Methods

Thirty male stroke patients aged from 45 to 55 years were enrolled in this study. Patients were selected from the Out Patient Clinic of the Faculty of Physical Therapy, Cairo University in the period from the beginning of October 2013 to the end of March 2014. Patients were divided into two equal groups. The first group (Group I) received a program of reach to grasp training with trunk restraint and the second group (Group II) received the same program without trunk restraint.

The patients were diagnosed as having stroke in the domain of carotid system based on careful clinical assessment by a neurologist and radiological investigations including computed axial tomography or magnetic resonance imaging of the brain. Patients participated after signing a written consent forms approved by the Ethics Committee of the Faculty of Physical Therapy, Cairo University.

Inclusion criteria were duration of illness ranged from six months to one year. The muscle tone of affected upper limb ranged from 1 to 2 according to Modified Ashworth Scale (MAS) [9] for muscle tone grading. Moderate arm motor impairment (between 30 and 49 scores) on the Fugl-Meyer (FM) arm section scale according to Michaelsen et al., [10]. Ability to reach to targets within 80% of arm length without sliding hand along table. Normal vision and hearing.

Exclusion criteria include patients who had receptive aphasia, apraxia, unilateral spatial neglect, visual or auditory defects, recurrent stroke, other neurological disorders affecting the reaching to grasping ability such as ataxia, orthopaedic disorders affecting the reaching to grasping ability such as stiffness of arm and peripheral nerve injuries, shoulder pain, deep sensory loss, medically unstable and uncooperative patients.

- For clinical evaluation:

  Modified Ashworth Scale for assessment of muscle tone and upper extremity impairment for all patients was evaluated as inclusion criteria with the arm section of the FM scale. This scale includes 4 motor subitems. Each item was rated on a 3-point scale (0 = Cannot perform; 1 = Partially performs; 2 = Performs fully) for a 66-point maximum [10]. This test was done pre and post treatment.

- For kinematic analysis:

  Two-Dimensional (2D) Motion Analysis System: It required a digital video camera and a digitizing software program [11]. It was used to measure trunk displacement and elbow extension ROM.

A- Evaluation session:

  Assessment of arm motor impairment using the FM arm section scale. This test was done pre and post treatment.

  For kinematic analysis. On pre-and post-tests, Patients seated on chair with their trunk unrestrained. Sitting position is standardized: Hip and knee joints flexed to 90° and feet supported on the floor. In the initial position, the reaching arm was close to the body, and rested on patient’s lab with the forearm pronated at elbow height (elbow flexed to 90°). After a command, each patient reached and grasped a target by the affected arm at his preferred speed using whole-hand grasping. The distance of the target corresponds to the patient’s wrist crease with fully extended elbow (80% arm’s length) [10]. Five markers were placed on the following bony landmarks; Ipsilateral acromion, lateral epicondyle, centre of dorsal aspect of the wrist, base of middle finger and middle of iliac crest according to Mohammed et al., [12].

B- Training session:

  All patients in the study group (GI) received program of reach to grasp training for almost an hour three times per week for five successive weeks (total of 15 sessions) according to Michaelsen et al., [10]. Trunk movements were prevented by body and shoulder belts attached to the chair back. Intervention was based on motor learning concepts
of type and scheduling of feedback and intensity according to recommendations suggested by evidence-based practice guidelines [13] using box and block and Purdue Peg board training. Rest periods of one to two minutes were permitted when necessary to avoid fatigue. All patients in the second group (GII) received the same program without trunk restraint.

All patients in two groups received the selected physical therapy program (Postural control and balance activities, Bobath technique, upper extremity control, proprioceptive neuromuscular facilitation (PNF), weight bearing and weight shift exercises as modified plantigrade, lower limb control and gait training).

Data analysis: Trunk displacement was calculated from sagittal movement of acromion marker from the edge of the chair in millimeters. Elbow extension ROM was formed by the vectors formed between acromion and lateral epicondyle line and lateral epicondyle and wrist line.

Statistical analysis:

Descriptive statistics were done in the form of mean and standard deviation for age, duration of illness, arm impairment, trunk displacement and elbow extension ROM. Paired \( t \)-test was used to assess changes within groups and un-paired \( t \)-test used to assess the changes between the two groups. Analysis was done using SPSS version 18. The alpha point of 0.05 was used as a level of statistical significance (when \( p \leq 0.05 \) is usually classed as “significant”, \( p \leq 0.01 \) as “highly significant” and \( p \leq 0.001 \) as “very highly significant”) [14].

Results

Demographic and clinical characteristics of the patients in both groups:

No statistically significant difference between both groups regarding mean age, duration of illness and motor impairment (\( p=0.436, p=0.1295 \) and \( p=0.1821 \) respectively) (Table 1). In GI, nine patients had left sided hemiparesis and six patients had Rt sided hemiparesis while in GII, Six patients had left sided hemiparesis and nine patients had right sided hemiparesis.

I- Comparison of trunk displacement and elbow extension ROM within groups:

Group (I):

There was a statistically very highly significant decrease in trunk displacement score post treatment in GI (\( p=0.0001 \)). The mean value of trunk displacement was 116.50mm pre treatment and 45.60mm post treatment. Also, there was a statistically very highly significant increase in elbow extension ROM score post treatment in GI (\( p=0.0001 \)). The mean value of elbow extension ROM was 51.40º pre treatment and 59.2º post treatment (Table 2, Figs. 1,2).

Group (II):

There was a statistically significant increase in trunk displacement score post treatment in GII (\( p=0.0227 \)). The mean value of trunk displacement was 129mm pre treatment and 145.60mm post treatment. Also, there was a statistically very highly significant decrease in elbow extension ROM score post treatment in GII (\( p=0.0001 \)). The mean value of elbow extension ROM was 53.53º pre treatment and 50.27º post treatment (Table 2, Figs. 1,2).

II- Comparison between both groups as regarding trunk displacement and elbow extension ROM pre and post treatment:

There were no significant difference in the mean values of trunk displacement and elbow extension ROM between GI and GII pre treatment (\( p=0.4967 \) and \( p=0.2223 \) respectively). There were a statistically very highly significant difference in the mean values of trunk displacement and elbow extension ROM between GI and GII post treatment (\( p=0.0001 \) and \( p=0.0002 \) respectively) (Table 3, Figs. 3,4).

Table (1): Demographic and clinical characteristics of the patients in both groups (GI and GII).

<table>
<thead>
<tr>
<th>Demographic and clinical characteristics</th>
<th>GI</th>
<th>GII</th>
<th>Comparison</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Age (year)</td>
<td>47</td>
<td>5.490</td>
<td>48.33</td>
<td>3.559</td>
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<td>Duration of illness (months)</td>
<td>9.670</td>
<td>1.543</td>
<td>10.47</td>
<td>1.246</td>
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<td>FM score</td>
<td>39.33</td>
<td>3.519</td>
<td>37.33</td>
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Table (2): Comparison between pre and post treatment mean values of trunk displacement and elbow extension ROM in both groups.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Pre-treatment</th>
<th>Post-treatment</th>
<th>Mean difference</th>
<th>t-value</th>
<th>p-value</th>
<th>Significance</th>
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</thead>
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<tr>
<td></td>
<td>Mean±SD</td>
<td>Mean±SD</td>
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<tr>
<td><strong>Trunk displacement:</strong></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>GI</td>
<td>116.50±34.85</td>
<td>45.60±13.12</td>
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<td>5.627</td>
<td>0.0001</td>
<td>***</td>
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<td>GII</td>
<td>129.0±31.55</td>
<td>45.60±13.12</td>
<td>16.59</td>
<td>2.558</td>
<td>0.0227</td>
<td>S</td>
</tr>
<tr>
<td><strong>Elbow extension ROM:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GI</td>
<td>51.40±2.823</td>
<td>59.20±5.519</td>
<td>7.800</td>
<td>5.954</td>
<td>0.0001</td>
<td>***</td>
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<tr>
<td>GII</td>
<td>53.53±5.986</td>
<td>50.27±5.688</td>
<td>2.600</td>
<td>3.129</td>
<td>0.0074</td>
<td>**</td>
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</tbody>
</table>

ROM : Range of motion.
SD : Standard deviation.
P : Probability.
S : Significant at p≤0.05.
HS : Highly significant at p≤0.01.
VHS : Very highly significant at p≤0.001.

Table (3): Comparison of the mean values of trunk displacement and elbow extension ROM between both groups pre and post treatment.

<table>
<thead>
<tr>
<th></th>
<th>Trunk displacement</th>
<th>Elbow extension ROM</th>
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<tr>
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<td>Pre-treatment</td>
<td>Post-treatment</td>
</tr>
<tr>
<td></td>
<td>GI</td>
<td>GI</td>
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<tr>
<td>Mean</td>
<td>116.50</td>
<td>129.0</td>
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<tr>
<td>SD</td>
<td>34.85</td>
<td>31.55</td>
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<tr>
<td>Mean difference</td>
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<td>−100</td>
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<td>t-value</td>
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<td>p-value</td>
<td>0.4967</td>
<td>0.0001***</td>
</tr>
<tr>
<td>S</td>
<td>NS</td>
<td>VHS</td>
</tr>
</tbody>
</table>

ROM : Range of motion.
SD : Standard deviation.
P : Probability.
NS : Non-significant.
VHS : Very highly significant at p≤0.001.

Fig. (1): Comparison between pre and post treatment mean value of trunk displacement in both groups.

Fig. (2): Comparison between pre and post treatment mean value of elbow extension in both groups.
Discussion

In the present study, there was a significant reduction of trunk displacement in GI, while there was a significant increase of trunk displacement in GII. This agreed with Cristea et al., [15] and Schneiberg et al., [16] who reported that there was an increase in compensatory movements with unrestricted practice in stroke patients and in children with mild cerebral palsy after 3 weeks of constraint-induced therapy respectively. McCrea et al., [17] also, mentioned that constraints from stroke impairments can result in the need for additional degrees of freedom at other joints such as movement compensations of the trunk during reaching. Michaelsen et al., [10] also found that the moderate trunk restraint group had a significant reduction of trunk displacement but moderate task specific training groups had significant increase of trunk displacement. Moreover, results of this study agreed with Wee et al., [18] who concluded that trunk restraint reduced excessive trunk movement during reaching.

Results of this study contradict with Michaelsen and Levin [19] who reported that task specific training with trunk restraint and without trunk restraint decrease trunk displacement post treatment. The contradiction between studies may be attributed to different methodology and training used, as in this study, the second group practice task specific training without trunk restraint nor verbal instruction not to move trunk but in the study of Michaelsen and Levin [19] practiced task specific training while verbally instructed not to move the trunk.

The reduced scores of trunk displacement in GI may be due to prevention of compensatory forward trunk displacement by trunk restraint but the increased score in GII may be to enable the patients to adequately reach the target placed within the length of the arm, accompanied with limited shoulder flexion and elbow extension ROM. It has been suggested that excessive trunk recruitment may be an adaptation of the nervous system during early recovery from stroke, to obtain a short-term reduction of the disability [20]. However, this compensatory strategy may be maladaptive and detrimental in the long term since, by providing an alternative method for the hand to reach an object, the system is less motivated to use a solution requiring recovery of lost movement elements (such as elbow extension and shoulder flexion) [4].

Cirstea and Levin [4] mentioned that patients with poorer motor recovery used more trunk displacement to compensate limited active joint ranges of the hemiparetic arm. The excessive trunk displacement is thought to be due to the fact that the control of trunk is bilaterally organized and therefore less affected than that of the arm by the unilateral hemispheric lesion. Another possible explanation is that the results of excessive trunk displacements is thought to be a compensatory behavior emerging from the efforts of spared cortical and subcortical system systems to compensate for lost control over motor functions such as elbow extension [21].

In the present study, there was significant increase in elbow extension ROM in GI, while there was a significant reduction of elbow extension
ROM in GII. The results of the present study come in agreement with Michaelsen et al., [10] and Woodbury et al., [8] who reported that trunk restraint group significantly increase elbow extension ROM in trunk restraint group but the non restraint group did not gain.

Significant increase of elbow extension ROM in GI may be attributed to use of trunk restraint. Hemiparetic patients use abnormal interjoint synergies to accomplish arm movement [22]. The arm extension synergy is characterized by scapular elevation and protraction together with shoulder extension, adduction and internal rotation, elbow extension, and wrist flexion. Limiting components of this synergy (scapular protraction and elevation) by trunk restraint may encourage the recovery of combined shoulder flexion and elbow extension [5].

The effects of trunk restraint indicate that hemiparetic patients do not use their potential joint range for free arm movements. A likely explanation stems from the findings of Levin et al., [23] who defined articular ranges in which hemiparetic patients could make isolated elbow flexion and extension movements by using a reciprocal muscle activation pattern. The angular range was correlated with the motor deficit such that the most severely affected patients could only make isolated elbow movements in midrange. With further encouragement, movement beyond the defined ranges was possible, but this required more effort and was accompanied by a pattern of excessive agonist/antagonist coactivation. For elbow extension, the excessive coactivation occurred when patients attempted to extend the elbow beyond the angular position defined by the static stretch reflex threshold for the antagonist elbow flexors. It may be postulated that restriction of trunk movement enabled patients to extend their reach by using the joint range characterized by coactivation. The additional energy cost of using more elbow extension probably was avoided by hemiparetic individuals when reaching without trunk restraint.

The increase in joint ranges with trunk restraint may be partly due to an adaptation involving anticipation of changed external load conditions or the adaptation was triggered by somatosensory input from the trunk or shoulder caused by the trunk restraint [24]. The finding that trunk restraint led to an increase in active angular range in hemiparetic patients suggests that patients may have retained the ability to adapt their motor commands to new external conditions [5].

Reaching patterns (arm ROM and interjoint coordination) changed during the period of trunk restraint [5]. However, it is difficult to determine whether improvements were a result of the stabilizing effect of the external trunk support or to a reorganization of the arm degrees of freedom by the central nervous system to accomplish the task. Results of the present study, showing an improvement of reaching pattern after restraint removal, support the latter mechanism. Trunk restraint allowed patients with hemiparetic stroke to make use of arm joint ranges that are present but not normally recruited during unrestrained arm-reaching tasks. Thus, the underlying “normal” patterns of movement coordination may not be entirely lost after stroke. In view of the results of this study, recovery of reaching movement post stroke differed according to therapeutic intervention, motor compensation used for reaching movements in the affected upper limb in stroke patients are mainly to enable the patients to adequately reach the target placed within the length of the arm accompanied with limited shoulder flexion and elbow extension ROM. Repetitive training of unrestrained reaching may reinforce undesirable compensatory strategies. Restriction of trunk should be used even in patients with chronic hemiparesis to encourage maximal use of available degrees of freedom. Trunk restraint may also be a useful technique in the acute phase of stroke to promote maximal arm motor recovery.

Conclusion:

The present study showed that limitation of compensatory trunk movement by trunk-restraint may be an essential element to include during training of reach to grasp for stroke patients with moderate arm impairment. Also, the present study showed that trunk restraint allowed patients with stroke to make use of arm joint range (elbow extension) that are present but not normally recruited during unrestrained reach to grasp task.

References

