Mechanisms of functional adaptation of post stroke patients during upper limb rehabilitation.

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INTRODUCTION

Stroke is a leading cause of disability of the adult population worldwide. Successful recovery of upper limb motor function occurs only in 20% of cases [1]. Upper limb motor recovery is a most challenging goal, due to lack of patient's motivation, training intensity and pathological synergy which is very difficult to correct using traditional methods. Poststroke upper limb paresis, spasticity and caused by them pathological synergies is the main problem on the way to daily living activities recovery. The problem of pathological synergies correction and transformation in rehabilitation practice are linked with the complexity of the required motor training approach [2]. A combination of cost-efficient, task-oriented, isolated and complex movement training with biofeedback is required to make synergy a compensatory mechanism for daily activities instead of pathological synkinesia.

A promising but insufficiently studied method is virtual reality (VR), as well as its combination with other techniques like arm weight support training. Motor training in virtual reality (VR) with arm weight support creates the necessary facilitated environment for motor skills relearning [3].

MATERIALS AND METHODS.

45 patients (27 males and 18 females) with medium age 55 [45;65] years were enrolled in this study. All patients had one supratentorial lesion due to ischemic or hemorrhagic stroke (confirmed by MRI). Medium stroke age was 7 [4;12] months. All patients had moderate to severe upper limb paresis measured by Medical Research Council Scale for Muscle Strength and Fugl-Meyer assessment of physical performance (FMAS) upper extremity subscore 45 [35;55]. All patients received 2 weeks of a rehabilitation course, 5 days per week, 45 minutes daily.

Main group (n=25) received 10 training sessions 45 minutes each on Armeo Spring system with separately adjusted weight support for shoulder and forearm and VR imitation of daily living activities such as reaching and grasping. The session includes 10 games like exercises and consistent increase of degrees of freedom from shoulder to the wrist. This condition allows teaching the patient voluntarily prevent pathologic synergy while performing a motor task.

The control group (n=20) received conventional therapy sessions with arm weight support (a system of pulleys), visual feedback (via mirror) and comparable set of tasks – reaching, grasping, manipulating objects.

Figure 1. Arm weight support training
Figure 2. Virtual reality with arm weight support training

For primary outcome assessment was used Fugl-Meyer assessment scale for upper limb, Action Research Arm Test (ARAT), Ashworth scale and Frenchay arm test. For motion analysis was used Russian Motion Capture System (Biosoft 3D). The paradigm for biomechanical analysis was presented with the functional reaching test. The reaching test was performed before and after the training course. Sitting at the table patient had to reach and grasp an empty glass located in front of him on the distance of extended healthy arm. For primary outcome were chosen reaching trajectory and arm kinematics, but patients were instructed to focus on the grasping movement to keep reaching movement more automatic. Normal reaching pattern was investigated on 10 healthy volunteers.

Figure 3. The reaching test.

RESULTS.

In our study, the clinical assessment (FM and ARAT scales) showed that paretic hand recovery was found more in patients with moderate and severe paresis. Statistically significant improvements in the arm motor function (FMAS) were found in both groups. However, subsection analysis revealed that the patients of the main group compared to the control group had a more significant improvement in wrist movements. In ARAT was found that in patients with moderate paresis significant improvements occur in both main and control groups. In patients with severe paresis, improvements were observed only in the main group.
FMAS Total (Before)

FMAS Total (After)

p = 0.000163

p = 0.000025
However, after motion analysis, a different stereotype of movement recovery was found in different groups of patients. In patients with severe paresis, an increase in the deviation of the movement pattern from the physiological movement was observed. At the same time, the normalization of the motor pattern was noted in patients with moderate paresis.

The time of reaching test execution in patients with severe paresis after rehabilitation was longer than before and exceeded the normal time more than twice. Curiously, these changes in patients with severe paresis were associated with an increase in functionality in the paretic arm (p>0.05).

Table 1. Time of reaching test.

<table>
<thead>
<tr>
<th></th>
<th>Before rehabilitation</th>
<th>After rehabilitation</th>
<th>p-level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate paresis, Me [25%;75%]</td>
<td>1.5 [1.24; 1.71]</td>
<td>1.26 [0.9; 1.62]</td>
<td>p=0.045</td>
</tr>
<tr>
<td>Severe paresis, Me [25%;75%]</td>
<td>2.25 [1.65; 3.76]</td>
<td>2.66 [1.11; 3.05]</td>
<td>p=0.043</td>
</tr>
<tr>
<td>Normal, Me [25%;75%]</td>
<td>0.96 [0.87; 1.16]</td>
<td></td>
<td></td>
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</tbody>
</table>

The kinematic parameters such as elbow extension, shoulder abduction and angular velocity in shoulder and elbow joints after rehabilitation were worsened. After a rehabilitation course was founded decreasing of the angular velocity of the elbow joint extension, increasing of the angular velocity of the shoulder joint, decreasing of the flexion in the shoulder joint and angular speed of the elbow joint extension.

Figure 4. FM and ARAT scales before and after rehabilitation.

Control

Main

ARAT (Before)

ARAT (After)

p=0.001474

p=0.00006
Table 2. Kinematics parameters in severe hand paresis.

<table>
<thead>
<tr>
<th>Movement</th>
<th>Before rehabilitation, Me [25%;75%]</th>
<th>After rehabilitation, Me [25%;75%]</th>
<th>p-level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elbow extension</td>
<td>124 [116;126]</td>
<td>112 [109; 125]</td>
<td>0,01</td>
</tr>
<tr>
<td>Shoulder flexion</td>
<td>36 [27; 41]</td>
<td>21 [20; 32]</td>
<td>0,02</td>
</tr>
<tr>
<td>Shoulder abduction</td>
<td>10 [10; 17]</td>
<td>19 [18; 22]</td>
<td>0,04</td>
</tr>
<tr>
<td>Velocity shoulder abduction</td>
<td>17 [13; 20]</td>
<td>48 [39; 65]</td>
<td>0,02</td>
</tr>
<tr>
<td>Velocity elbow extension</td>
<td>39 [26; 69]</td>
<td>29 [18,39]</td>
<td>0,02</td>
</tr>
</tbody>
</table>

The analysis of trunk movements in severe paresis patients was shown that after rehabilitation course the trunk compensatory strategy was increased (trunk was mowed forward when patient reach the glass). These changes were associated with an increase in functionality in the paretic arm (p>0,05).

Table 3. Body displacement in reaching test.

<table>
<thead>
<tr>
<th>Shoulder displacement</th>
<th>Before rehabilitation, Me [25%;75%]</th>
<th>After rehabilitation, Me [25%;75%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Healthy shoulder</td>
<td>23 [19,8; 57,44]</td>
<td>66 [49;81]</td>
</tr>
<tr>
<td>Paretic shoulder</td>
<td>169 [88; 178]</td>
<td>215 [162; 229]</td>
</tr>
</tbody>
</table>

CONCLUSIONS.

If we summarized data of clinical and biomechanical parameters we see, that patients with severe paresis formed the new compensatory strategy of motion. Because of the significant changes in functional recovery are combined with worsened of biomechanical parameters.

It is believed that it is the resistance to pathological synergies and the forced training in physiological movement is the most effective method. However, correction of pathological synergies allows developing the most energy-efficient stereotype of movements for patients with regard to their individual capabilities. Combined VR and weight support training can be more effective to restore the impaired motor function after stroke than conventional weight support training. This approach contributes to the motor pattern reorganization through biomechanical and visual feedback, projected into the virtual space.

REFERENCES

