Early upper limb rehabilitation: Its effect on hand function in traumatic brain injury patients

M.N. El-Bahrawy¹, G. Mousa¹, M. Sawan²
Department of Neuromuscular Disorders and its Surgery¹, Faculty of Physical Therapy
Department of Neurosurgery², Cairo University

ABSTRACT

The purpose of this study was to evaluate the predictive value of early upper limb training program for subsequent hand movements and function. Thirty right handed patients with traumatic brain injury managed between January 2001 and January 2002, They were manifested by hemiparasis, the patients were matched for their age, sex, severity of lesion (according to Glasgow Coma Scale scores), level of upper limb function (according to Motoricity index scale) and level of functional status (according to Barthel index scale). They were classified according to the level of lesion as the study group reached its stability level early (after three weeks of injury) while the control group reached its medical stability level lately (after six weeks). Both groups received a rehabilitation program toward restoring upper limb movements based on passive movement for all involved upper limb joints, approximation, proprioceptive neuromuscular facilitation (PNF) and neuromuscular electrical stimulation on the shoulder abductors, wrist and fingers extensors. Hand grip, thumb/index strength and fingers dexterity were assessed before and after two months of treatment program. The results revealed that early upper limb training program predicted significant improvement in hand and fingers strength and function. It can be concluded that the early upper limb rehabilitation may be effective in recovery of hand function in hemiparetic patients consequently to traumatic brain injury. (Egypt J. Neurol. Psychiat. Neurosurg., 2004, 41(1): 283-294).

INTRODUCTION

Traumatic brain injury (TBI) has been described as an epidemic with an estimated 500,000 to 1.5 million admission annually¹. Brain injuries occur in a trimodal distribution with the highest incidence in children (younger than 5 years old), young adults (16 to 34 years old) and older people (65 years and older)². The medical system will need to care for an increasing number of young adults with TBI⁴.

Moreover traumatic brain injuries are the leading cause of death among the entire population². The impact of injury in terms of mortality is well known, but there is relatively little information on the extent and severity of permanent disability resulting from trauma which is defined as any restriction or lack of ability to perform an activity in a manner within the range considered normal for a human being⁴. The ultimate goal of traumatic head injury care is to restore patients to their previous functional status and role in the society⁵.

Following brain injury many patients are left with persistent motor disability that often involves upper limb, 25% regain some
functions and 5% regain full upper limb functions\(^6\). For patients who have difficulty on residual control of the wrist and fingers there is an increased likelihood of useful hand function returning\(^7\), but they may not be able to achieve full functional recovery because of contractures\(^8\). Development of contractures may be attributed to spasticity\(^9\) or due to muscular weakness, which lasts for long periods\(^10\).

Adequate control of wrist movements is a requisite for skilled distal movements, such as handwriting. Performance of skilled distal movements is often impaired and parameters such as movement velocity may be altered in adults with hemiparesis secondary to traumatic brain injury\(^11\).

Low intensity neuromuscular electrical stimulation of wrist extensor muscles has been shown to reduce flexor spasticity\(^12\) and increase range of wrist extension\(^13\). Furthermore, stimulation approaching, but not exceeding the gross motor threshold may facilitate voluntary recruitment\(^14\).

In an attempt to combine these benefits, we considered the use of non contingent, neuromuscular electrical stimulation of upper limb (wrist and fingers extensors and shoulder abductors) combined with passive and active exercises program to the upper limb may improve muscle balance by reducing spasticity, enhancing the excitation of extensor muscles relative to flexors and in turn improve the hand functions in early stage of hemiparesis secondary to traumatic brain injury.

**The purpose of this study** was to evaluate the efficacy of early rehabilitation program in enhancing upper extremity motor recovery particularly the hand function in hemiparetic patient consequent to traumatic brain injury.

### MATERIALS AND METHODS

1) **Subjects selection:**

Thirty right handed patients from both sexes (17 males and 13 females) participated in this study. They were diagnosed clinically and radiologically as having closed TBI (traumatic brain injury). All the patients were preexisting a history of neurological condition in the form of hemiparesis. They were selected at the time of discharge from Acute Inpatient Care Unit, Kasr El Aini Hospitals, Cairo University.

Information regarding the mechanism of injury was obtained and revealed comparable injury pattern between all the patients. High velocity injuries (e.g. motor vehicle related accidents) were the primary cause of injury (65%), and approximately one third of the patients sustained low velocity injuries (e.g. assaults, falls etc.). The reminder of the sample were injured from direct trauma. Their mean age was 31±1.62 years.

Informed consent was obtained from the patients or responsible family member.

**Inclusion criteria:**

- All the patients screened by plain X-ray, CT and MRI on the brain. They selected if they had closed TBI and medically stable, some for them reached the medical stability level early after three weeks of injury and the others reached lately after six weeks.

- All the patients had minor to moderate injuries according to Glasgow coma scale (GCS)\(^15\) which is used to determine the level of consciousness and to infer the severity of injury with score ranges from 3:15. All the patients had a high level function according to motor response subtest of the GCS\(^16\).
The patients suffered from hemiparesis with spasticity (resistance to passive movement) at wrist of the involved arm of grossly a mild (grade 1: II) degree of spasticity according to scores of modified Ashworth's scale. They were able to simultaneously flex the shoulder to 90° and fully extend the elbow according to the Motocility index/scale. They were able to follow simple directions and were not taking any medication to reduce spasticity during the study.

The patients were divided into two groups (study & control groups) according to the level of injury as the patient in the study group (G2) reached medical stabilization level early within three weeks after injury, while the control group (G1) reached its stability level after six weeks.

Exclusion criteria:
Patients were excluded if they had: neurological complications including cerebrospinal fluid leak, infection, hydrocephalus, herniation syndrome or intracranial hypertension. They were excluded also if they had previous cranial operations or CVA and orthopedic constraints on the use of involved shoulder, elbow or wrist.

2) Instrumentations:
A. Instruments used for evaluation:
1. Galsgow coma scale (GCS) is used to define mild and moderate head injury. Patients with a GCS of 9:12 are regarded as having moderated head injury whereas, patients with a GCS of 13:15 are regarded as having mild injury.
2. Jamar Hand Dynamometer (Model No. 1528, U.S.S.R) was used to measure grip strength (in pounds). It allows five handle positions (first position = smallest, fight position = widest).
3. Finger tester dynamometer (Model No. 360 SR, U.S.A.) was used to measure relative finger strength (in pounds) as tester is squeezed between thumb/index or middle finger. Medium tests (0:20) and strong tests (0:30)
4. Barthle index, was used to record the ability to perform basic activities of daily living and mobility (including transfers, walking and climbing the stairs). It is scored by either self report or observation of the patient and for each item the patient is scored according to the amount of help needed.
5. Purdue peg board test (PPBT) was used to assess the hand and finger dexterity. It consists of a group of metals which were different in shape and size about 126 in numbers place in form suitable rounded places. The chart contains forty four holes in two columns.

B. Instrument used for treatment:
Neuromuscular electrical stimulation unit (model number UPP4, manufactured at UK). The unit has the following specifications: It produces asymmetrical biphasic pulse width with a pulse width of 300 ms, stimulation frequency: 10-100 Hz, relaxation time: 0.5-50 sec., treatment timer 5-60 sec. which is continuous and rises up to 400 sec.

3) Procedures
I. Evaluation protocol:
a. All the patients were interviewed guided by a history taking and neurological sheet. The severity of injury and stage of lesion were graded by using GCS.
b. Muscle tone of upper extremity muscles was graded according to modified Ashowrth's scale.
c. Grip strength was measured by using Jamar dynamometer. Instructions were given to the subjects as the following:
- Proper handling of the dynamometer with the upper most handle resting on the thenar eminence.
- Adequate provision for the fingers to maintain a firm grip on the lower adjustable arm of the dynamometer.
- A clear command "to squeeze the handle of the dynamometer as hard as possible" and to hold it in place five seconds. No verbal encouragement were offered during the test with each experimental condition, three attempts were made and the average was recorded for the test. Before testing, the subject's shoulder was adducted and neutrally rotated while the forearm and wrist joint were held in neutral position.

d. Precision of opposition grip with the thumb & index fingers was measured by using finger tester dynamometer.

e. Levels of self care, continence, mobility, communication and transfer were measured according to Barthel index scores.

f. The Purdue peg board test (PPBT) was used to assess fingers and hand dexterity. The chart was placed at suitable height (e.g. on the table), the patient assumed sitting position while his/her neck in neutral position. Both shoulders at the level, arms and forearms supported on the table. The patient carried out the order of the test, and the average of three trials was recorded per minute.

II. Treatment protocol:
The patients were divided into two equal groups according to the medical stabilization (G1 & G2). The control group (G1) started the treatment program lately (after six weeks of injury) while the study group (G2) started the treatment program early (after three weeks of injury). The treatment program was provided for an average of one hour three sessions per week for two months. Both groups received exercises program in the form of:
- Passive ROM for whole upper extremity.
- Prolonged stretch for spastic groups at wrist, elbow and shoulder.
- Approximation training.
- Strengthening active exercises were applied in the form of Proprioceptive Neuromuscular Facilitation (PNF) approach encompasses the whole upper limb including handopening (flexion, abduction & external rotation pattern with elbow extended).
- During active training, verbal instructions to both groups were exactly the same to eliminate instructions induced changes in kinematics. The patients were instructed either to complete a slow movement or to move "as fast as possible". In both cases the patient was instructed to hold the end position and the movement needed to end within the target range. Each patient was allowed rest period of ten to twenty seconds between each movement for at least ten repetitions.
- Neuromuscular electrical stimulation program: Both groups received surface neuromuscular stimulation to produce wrist and fingers extension and shoulder abduction. Extension of the wrist was achieved by the stimulation of the wrist and fingers extensors (extensor carpi radialis longus, extensor carpi radialis brevis, extensor carpi ulnaris, extensor digitorum and extensor pollicis muscles). In addition to wrist extensors, stimulation was used over shoulder abductors, one electrode on supraspinatus, and another electrode on middle fibers of deltoid. The patient's position was sitting, elbow flexed to 90°, forearm supported in pronation and the wrist balanced without ulnar or radial deviation. The treatment period was 30 min. per session.
4) **Statistical analysis:**

Descriptive statistics in the form of the means and standard deviation were calculated for all variables. Non parametric tests were used to examine the difference between both groups regarding severity of lesion (highest & lowest GCS scores) and functional status variables (according to Barthel index scores) in the from of Mann-Whitney U tests. Independence t-tests were performed to examine the differences between the two groups regarding to grip strength, hand perhension and hand dexterity pre and post treatment program.

**RESULTS**

The mean values of hand grip, thumb/index strength and fingers dexterity for each group pre and post treatment was calculated. Comparison was done within each group and between both groups (G1 & G2) pre and post treatment program.

Table (1) revealed that both groups (G1 & G2) were matched in their age, severity of lesion (according to GCS scores) and level of functional status (according to Barthel index scores). Results revealed that both groups matched in all variables.

Handgrip strength for each group pre and post treatment program was calculated. Comparison was done within each group and between both groups (G1 & G2) pre and post treatment program.

Table (2) and Figure (1) compare the mean values of hand grip strength (in pounds) within the first and second groups (G1 & G2). The results revealed that there was a highly significant difference of hand grip strength in each group with a p-values of 0.0001. These comparisons showed that both groups (G1 & G2) manifest significantly high values for hand grip strength after treatment program compared to before treatment.

Comparison of hand grip strength of both groups (G1 & G2) pre and post treatment program illustrated in table (3) and figure (2), the results revealed that there was no significant difference between both groups before starting the treatment program (P>0.05). Post treatment significant difference was observed between both groups which indicated improvement in hand grip strength in (G2) that received rehabilitation program early (after three weeks of injury) compared to the first group which started program of treatment lately.

The same trend was obtained from results of thumb/index perhension strength as there was a significant difference between values of pre & post treatment program within each group (G1 & G2) as presented in table (4). Comparison between mean values of pre & post treatment in both groups (G1 & G2) revealed that there was no significance between both groups in pre-treatment values while there was highly significant difference between post treatment values (Table 5 & Fig. 3). These comparisons indicated that there was improvement in hand perhension (thumb/index) in the second group (G2) that started the treatment program early compared to the first group (G1) which started the treatment lately.

These results indicated that there was high improvement in fingers dexterity in the second group compared to the first group after treatment program.

On comparing the first group (G1) before treatment and after treatment regarding to purdue peg board test, analysis of the results illustrated that the mean value of pre-treatment was (1.46±0.51) for group (G1) while it was (1.66±0.48) for G2 respectively. In addition, post treatment mean values was (1.59±0.53) for G1 and (2.73±0.88) for G2 respectively (Table 6).
Table 1. Characteristics of the patients in both groups (G1 & G2) including age, severity of lesion and level of functional status.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group</th>
<th>Mean</th>
<th>S.D</th>
<th>T-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>G1</td>
<td>31.93</td>
<td>1.90</td>
<td>0.00</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>G2</td>
<td>30.90</td>
<td>2.87</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severity of lesion (GCS scores)</td>
<td>G1</td>
<td>10.00</td>
<td>1.31</td>
<td>0.52</td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td>G2</td>
<td>10.27</td>
<td>1.49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Functional status (Barthel index scores)</td>
<td>G1</td>
<td>11.46</td>
<td>1.76</td>
<td>0.32</td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td>G2</td>
<td>12.01</td>
<td>1.31</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Significant * at 0.05

Table 2. Comparison between mean values of hand grip strength (in pounds) pre and post treatment within each group (G1 & G2).

<table>
<thead>
<tr>
<th></th>
<th>Group</th>
<th>Mean</th>
<th>S.D</th>
<th>T-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>G1</td>
<td>7.60</td>
<td>2.82</td>
<td>4.80</td>
<td>0.0001*</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>9.26</td>
<td>3.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G2</td>
<td>Pre</td>
<td>7.26</td>
<td>3.26</td>
<td>15.54</td>
<td>0.0001*</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>14.66</td>
<td>2.02</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Significant * at 0.05

Fig. (1): Mean values of hand grip strength pre and post treatment program within each group (G1&G2)
Table 3. Comparison between mean values of handgrip strength per and post treatment program in both groups (G1 & G2).

<table>
<thead>
<tr>
<th></th>
<th>Per treatment</th>
<th>Post treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>G1</td>
<td>G2</td>
</tr>
<tr>
<td>Mean ± S.D</td>
<td>7.60±2.82</td>
<td>7.26±3.26</td>
</tr>
<tr>
<td>T-Value</td>
<td>0.30</td>
<td></td>
</tr>
<tr>
<td>P-Value</td>
<td>0.77</td>
<td></td>
</tr>
</tbody>
</table>

Significant * at 0.05

![Graph showing mean values of handgrip strength pre and post treatment in both groups (G1 & G2).]

Fig. (2): Mean values of hand grip strength pre & post treatment program in both groups (G1 & G2).

Table 4. Comparison of hand perception strength (thumb / index) pre & post treatment within each group (G1 & G2).

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>S.D</th>
<th>T-Value</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>3.20</td>
<td>1.32</td>
<td>-4.58</td>
<td>0.000*</td>
</tr>
<tr>
<td>Post</td>
<td>3.80</td>
<td>1.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>3.73</td>
<td>1.98</td>
<td>20.87</td>
<td>0.000*</td>
</tr>
<tr>
<td>Post</td>
<td>10.00</td>
<td>2.26</td>
<td></td>
<td></td>
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</tbody>
</table>

Significant * at 0.05
Table 5. Comparison of hand perception strength (thumb/index) pre & post treatment between both groups (G1 & G2).

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>G1</td>
<td>G2</td>
</tr>
<tr>
<td>Mean ± S.D</td>
<td>3.20±1.32</td>
<td>3.73±1.98</td>
</tr>
<tr>
<td>T-Value</td>
<td>0.87</td>
<td></td>
</tr>
<tr>
<td>P-Value</td>
<td>0.39</td>
<td></td>
</tr>
</tbody>
</table>

Significant * at 0.05

![Image of Fig. 3](image-url)

**Fig. (3):** Mean values of hand perception strength (thumb/index) pre & post treatment in both groups.

Table 6. Comparison of precision (PPBT) pre & post treatment between both groups (G1 & G2).

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>G1</td>
<td>G2</td>
</tr>
<tr>
<td>Mean±SD</td>
<td>1.46±0.51</td>
<td>1.66±0.48</td>
</tr>
<tr>
<td>T. Value</td>
<td>-1.87</td>
<td></td>
</tr>
<tr>
<td>P. Value</td>
<td>0.08</td>
<td></td>
</tr>
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</table>

Significant* at & 0.05

**DISCUSSION**

The purpose of this study was to evaluate the effect of early upper limb rehabilitation on hand function of traumatic brain injury patients. This rehabilitation program included the combination of neuromuscular electrical nerve stimulation on shoulder abductors, wrist and fingers extensors, approximation of the upper limb; passive movements of upper limb joints and proprioceptive neuromuscular facilitation approach (PNF). The outcomes
were assessed in both groups pre-and post-treatment program. One group started the treatment program early after three weeks of injury; after reaching the medical stabilization level; while the other group started the treatment after six weeks of injury. Both groups had comparable baseline characteristics. Statistical analysis revealed significant recovery in hand function scores of the study group which started the rehabilitation program early (indicated by hand grip, thumb/index grip, and precision grip) than in the group that started the rehabilitation program lately.

It was widely accepted that the upper extremity function is the basis for the fine motor skills that is also important to achieve activities such as feeding, dressing, and grooming. In addition, upper extremity function plays an important role in gross motor skills such as walking, and the ability to recover balance and protect the body from injury, when balance recovery is not possible. Consequently the upper extremity control of both fine and gross motor skills and recovery of upper extremity functions are important aspects of retraining motor control and these fall within the purview of most areas of rehabilitation including both occupational and physical therapy.

Moreover, there were evidences of support that there were differences between power grip and precision grip. In respect to brain, the primary motor cortex fire only during the execution of a precision grip, not a power grip. This indicated that these connections are with intrinsic hand muscles rather than forearm muscles. These neurons show a short latency burs (about II msec.) prior to muscle activation, which suggests that they are monosynaptically connected to the motor neuron pools. This interpretation may support the reasons why the study group which reached the medical stability level early improved significantly in precision grip rather than the control group which reached the medical stability level lately.

After a central nervous system lesion, commands from the CNS may be altered, as well as the musculoskeletal components controlled by CNS. In general, most patients with head injuries, discharged home with impairment of functional activities, especially delicate and fine movements. Early physical therapy interventions and rehabilitation appeared to be important aspects with regard to recovery of functions. Generally, it is known that following a traumatic brain injury, any spontaneous recovery of upper limb motor function is limited to the first six months. During this period, motor recovery has been reported to be enhanced beyond that attained by conventional therapy, rehabilitation including neurofacilitatory physical therapy, and positional feedback with electrical stimulation. So, early rehabilitation of upper limb not only included proximal facilitation but also distal control to improve hand functions. This accounted for the improvement that was seen in this study after receiving proprioceptive neuromuscular facilitation (PNF) and passive movements earlier according to the methods described by Voss et al.

Moreover, effect of other techniques employing active patient involvement during proprioceptive neuromuscular facilitation have demonstrated improvements that are consistent with the results of this study. PNF pattern; flexion, abduction, external rotation with elbow extended triggered mechanically by voluntary shoulder abduction, elbow extension, wrist extension, produce increase in firing extensor pattern of upper limb which may guide the balance between flexors and extensors of upper limb. This active
involvement appears to be a common factor required for motor improvement and hand grip after traumatic brain injury.

It can be also pointed out that neuromuscular electrical nerve stimulation on shoulder abductors, wrist and fingers extensors produce the following effects: muscle contraction due to direct stimulation of the motor neuron, reduction of spasticity due to afferent stimulation\(^{31}\), an information effect from the joints and muscles afferents sensation, and visual perception of the movements produced.\(^ {21}\)

The result of this study demonstrated that specific type of therapy can improve paretic upper limb movement functions particularly the hand function which represent the final part to perform the different tasks.

Furthermore, there are some experimental data supporting the importance of active involvement to produce cortical remodeling. In primates, there is evidence to support that cortical representation of skin surfaces is remodeled by use throughout life such remapping of cutaneous receptive fields which enhanced by repeated tasks that produce cutaneous stimulation of a limited sector of skin on the distal phalanges\(^ {26}\). In addition, the upper limb includes the hand which is the most sophisticated neuromuscular apparatus. The arm and hand must feel, hold, and manipulate. These are more difficult tasks which are in need for highly integration and organization from CNS.\(^ {27}\)

So, there are physiologic limits to recovery, especially in upper extremity. As Waxman\(^ {34}\), pointed out the specificity of the pyramidal system imposes certain limitations on the degree of recovery that can be achieved after brain injury. Porter\(^ {27}\) stressed that destruction of the corticospinal tract produces permanent deficits in fine motor control that prevent recovery of isolated distal movements.

Finally, all of these facts must be taken into account during rehabilitation of the upper limb, the earlier the starting intervention, the more predicting improvement expected in hand function of paretic arm in post traumatic brain injured patients.

**Conclusion**

Despite of the difficulties of research on traumatic brain injured patients, it can be suggested that early rehabilitation of upper limb may achieve and maintain improvement in the upper extremity, especially the outcome of hand function.

**REFERENCES**

الملخص العربي
التأهيل المبكر للطرف العلوي وتأثيره على وظائف اليد في حالات ما بعد الإصابة المخية

هدف البحث: تحديد قيمة التأهيل المبكر للطرف العلوي على وظائف اليد في حالات ما بعد إصابات المخ.

أجريت الدراسة على ثلاثين مريضاً من الجنسين، يعانون من شلل نصفي طولي جزئي نتيجة لإصابة مخية من مستشفى القصر العيني جامعة القاهرة وتم تقسيمهم إلى مجموعتين من حيث درجة ثبات الحالة الطبية.

المجموعة التجريبية وصلت إلى درجة ثبات الطبلي في مدة ثلاث أسابيع أما المجموعة الضابطة فقد وصلت إلى درجة ثبات الطبلي متأخرًا (بعد ست أسابيع) من الإصابة.

وقد تم علاج المرضى جميعًا ببرنامج تأهيلي خاص مكون من تمارين للمرونة السلبية للذراع وترويب الأوجه الفصلية، ونموذج للتثبيت العصبي العضلي للطرف العلوي بالإضافة إلى التثبيت الكهربائي العضلي العصبي للعضلات المبعدة للذراع والعضلات الواقفة لمفصل الرسغ والأصابع.

وقد أسفرت النتائج عن تحسن ملحوظ في وظائف اليد والأصابع وقوة المسك للقيد في المجموعتين إلا أنها زادت إحصائياً في المجموعة التجريبية التي وصلت إلى درجة ثبات الطبلي مبكرًا عنها في المجموعة الضابطة التي وصلت إلى درجة ثبات الطبلي متأخرًا. أما بالنسبة للمهارة الحسية الحركية للأصابع فقد تحسنت فقط في المجموعة التجريبية، مما يثبت أن التأهيل المبكر لمثل هذه الحالات يؤثر تأثيرًا إيجابيًا على درجة المهارة الحسية الحركية للقيد والأصابع.