

Effect of Hand Function Training on Improvement of Hand Grip Strength in Hemiplegic Cerebral Palsy in Children

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Abstract

Objective: The aim of this work was to show the effect of hand functioning training on improvement of hand grip in hemiplegic cerebral palsy children.

Method: Thirty children were enrolled in this study and randomly assigned into two groups; group A (hand function training plus traditional physiotherapy program) and group B (traditional physiotherapy program only). Hand held dynamometer was used to detect and follow hand grip strength. This measurement was taken before initial treatment and after 12 weeks post treatment.

Results: Data analysis were available on 30 spastic hemiplegic cerebral palsy (cp) children and mean value of the hand grip strength in study group pre and post treatment had highly statistically significant differences of $p < 0.0001$ while the mean value of hand grip strength in the control group pre and post treatment had statistically significant difference of $p < 0.05$.

Conclusion: The combined effect of physiotherapy training plus the hand functioning training is recommended.

Keywords: Hand function training; Hemiplegic CP

Introduction

Hand function problems of hemiplegic C.P children are often associated with problems of motor control, sensibility and sensory processing and persistence of primitive grasp reflex. Past studies indicated that simple hand movements with hand splinting can facilitate hand function of children with CP by stimulating the redistribution of brain activity, which accompanies recovery of hand function, thus resulting in a reduced motor deficit. Improvements were shown in the active range of motion and grip strength [1].

Cerebral palsy is a group of permanent disorders of the development of movement and posture causing activity limitation that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. Secondary to the brain disturbance, children with cerebral palsy often experience neurological symptoms including dystonia, ataxia, athetosis and particularly spasticity [2,3].

Spasticity occurs as a result of a loss of upper motor neuron inhibition on the lower motor neurons which results in increased or impaired motor unit firing and altered muscle tone. Muscle spasticity is characterized by a velocity-dependent increase in tonic stretch reflexes (muscle tone) with exaggerated tendon jerks (phasic stretch reflex) resulting from hyper excitability of the stretch reflex. Adding to these neurological symptoms, skeletal muscle morphology in children with cerebral palsy is also altered due to abnormally long muscle sarcomere lengths and muscle tissue containing a hypertrophic extracellular matrix of poor quality. This results in muscle stiffness affecting posture and movement and can be described as hypertonia or increased muscle tone [4,5].

Occupational therapy training in children with hemiplegia is a commonly applied intervention. An essential element of the approach to upper limb training includes the repetitive practice of motivating, meaningful and purposeful outdoor training activities. This has been well supported by recent advances in the areas of neuroscience, basic mechanisms of hand function and more specifically, motor control and motor learning theories [6,7].

Material and Methods

Subjects

Thirty children from both sexes with hemiplegic cerebral palsy children were enrolled for this study, aged 4 to 6 years at time of recruitment because the children in this age are able to reach forward to an elevated position in front with mid range shoulder flexion, child is able to grasp a cube from a table top and release it in a large container, able to attend to tasks and follow simple one stage commands and he/she is able to actively perform reach and grasp/release activities with verbal prompting. Children who otherwise met the inclusion criteria were excluded if they had: previous BoNT-A injections in the upper limb in the past 12 months or prior upper limb surgery (i.e. tendon transfer/tendon lengthening).

Children randomized to the experimental group (A) received occupational therapy training plus traditional physiotherapy program. Children randomized to the control group (B) received traditional physiotherapy program only. The individual-based hand function treatment sessions of 45 to 60 minutes were conducted three times weekly for 12 weeks in an occupational therapy treatment room after the physiotherapy session for group (A). In addition, children in the experimental group were exposed to home routine program 3 hours daily for the 12 week treatment period. Control group (B) received a traditional physiotherapy program only.

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Outcome measurements

The clinical evaluation included history, and degree of spasticity as a characteristic of selection of sample not as a variable. All children were assessed for hand grip strength using hand held dynamometer. All measurements were taken at baseline (pre) and after 12-week of intervention (post).

Assessment of hand grip strength

To properly evaluate functional improvement in hand, performances following an UMN lesion, assessment tools need to be measured within the participation. Few quantitative tools exist to measure the behavior of spastic muscle during functional activity. Measurement of grip strength is a well established method for investigating hand function, providing insight into the combined action of extrinsic and intrinsic muscle groups. Hand-held dynamometers record the maximal grip strength attained during a period of effort, thereby assessing a subject's hand strength against normative data with excellent inter-rater and test-retest reliability.

Occupational therapists have commonly used hand grip and pinch strengths as baseline measures to evaluate hand function. Grip strength required to perform most occupations of daily living. Strength measurements are commonly combined with dexterity evaluations to provide a picture of hand function [8].

The patients performed the test while sitting comfortably with shoulder adducted and neutrally rotated forearm, elbow flexed to 90 degrees, and forearm and wrist in neutral position. The patients were instructed to perform a maximal isometric contraction. The test was repeated within 30 seconds and the highest value of three tests was used for the analysis.

Evaluative parameters for fine motor skills: The size, shape, weight, texture and slipperiness of the objects must be given careful consideration. Children can handle blocks and other objects with straight sides more effectively than round objects. Grasp of small tiny object should not be the priority for children, people use an opposed pattern to grasp items as a cup (cylindrical grasp), a ball (aspheric grasp), a telephone receiver and a large block. Children with disability should be assisted in developing skills of all types of opposed grasp pattern, power grasp, and lateral pinch to evaluate the skill acquisition [1,9].

Time, speed, accuracy and number of trials are movement parameters that have to be evaluated in fine motor skills: A small object require longer reaction time than larger object, the first part of the movement seems to be unaffected by object size but for smaller objects extra movement time is spent in the last part of movement when we increase the speed of a movement the accuracy will decrease [10].

We used the following graduation to follow the improvement in skill acquisition:

- a. big object, rectangular shape, rough, heavy
- b. big object, rectangular, rough, light
- c. big object, rectangular, smooth, heavy
- d. big object, circular, rough, heavy
- e. big object, rectangular, smooth, light
- f. big object, circular, smooth, heavy

- g. big object, circular, smooth, light
- h. big object, rectangular, rough, light
- i. small object, rectangular, rough, heavy
- j. small object, circular, rough, heavy
- k. small object, rectangular, smooth, heavy
- l. small object, rectangular, rough, light
- m. small object, rectangular, smooth, light
- n. small object, circular, smooth, heavy
- o. small object, circular, rough, light
- p. small object, circular, smooth, light.

Timing places high demands on the motor system for speed and efficiency with high demands for attention and perception. Reaction time provides an indication of an individual speed in preparing a response. Production of fast arm movement may be affected by poor attention [11].

Flexibility test for wrist and finger flexors: By gradual extension of the wrist to follow the tightness of wrist and finger flexors.

Intervention

For all children, the programs were conducted three times weekly, for 12 weeks. Each session lasted for 45 to 60 minutes in an occupational therapy room, in addition to 3 hours of home program, 7 days a week during the treatment period.

Both groups (A and B) received a traditional physiotherapy program, as the following

1. Hot packs to improve circulation and relax muscle tension applied on the wrist flexors for 20 minutes.
2. Facilitation of anti-spastic muscles (wrist extensors): tapping followed by movement, quick stretch, triggering mass flexion, biofeedback, weight bearing, clenching to toes, compression on bony prominence, rapping the muscle, approximation, vibration, irradiation to weak muscles by strong muscles, and ice application for brief time.
3. Prolonged stretch to wrist flexors to gain relaxation via techniques used as prolonged stretch (positioning, night splint, reflex inhibiting pattern, Bobath technique) for 20 minutes.
4. Passive stretching to tight muscles (wrist flexors) to destruct adhesions in muscles and sheath. It must be decent gentle gradual stretch not over stretch at all, lasting 20 second then relaxation 20 second 3-5 times per session then maintain the new range by using adjustable wrist splint after session for two hours then release for using the hand in ADL activity.
5. Graduated active exercise for upper limb muscles.
6. Gait training using aids in closed environment using obstacles, side walking followed by pass walking to stimulate protective reaction for the hand.
7. Balance training program which include static and dynamic training.
8. Faradic stimulation for wrist extensor to triggering wrist extension. To prevent cross electricity to reach wrist flexors because

these spastic muscles are more sensitive to electric stimulation than weak muscles. Mother was asked to support wrist in extension during electrical stimulation for 15 minutes.

The experimental group (group A) received specialized hand function training program as following

The main physical problem with hemi paretic child is that they have excess muscle tone in the hand. The main fine motor problems with hemi paretic child are inability to perform isolating finger movement, turning their hand over (palm up), holding their wrist at a proper angle, and grasping and releasing objects. The following methods help in restoring these functions.

Positioning of the child and the therapist: The most commonly used position for treatment and functional use of fine motor skills is sitting.

Specific treatment suggestions for enhancing supination

1. Facilitate supination with the forearm on a surface as in weight bearing on floor, or on mat, while seated at a table the therapist place an object in the child hand, the child attempt to compensate for difficulty with supination by using wrist extension.

2. Encourage the use of 45 to 90 degrees of supination followed by grasp of an object with elbow in 90 degrees of flexion, the child encouraged to keep thumb up as reaching and grasping large birthday candles then put them into cake that require supination.

3. Encourage lateral reach followed by grasp most of the children with limited use of supination find it easier to combine humeral abduction with external rotation and supination than to use humeral flexion with external rotation and supination. Object presented laterally to the child allow the child to use abduction and external rotation which allow for supination.

4. Encourage reaching by using shoulder flexion and external rotation by placing the object between leg and shoulder in sitting position depending on the child ability to control external rotation and supination while completing the reach.

5. Encourage reaching across midline following strategies suggested for reaching in front of the shoulder.

Grasping training

Grasp training can be conducted according to size, shape, weight, texture, time, speed, accuracy and number of trials.

The key element was the repetition of the task by graduation:

- a. big object, rectangular, rough, heavy
- b. big object, rectangular, rough, light
- c. big object, rectangular, smooth, heavy
- d. big object, circular, rough, heavy
- e. big object, rectangular, smooth, light
- f. big object, circular, smooth, heavy
- g. big object, circular, smooth, light
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p. small, circular, smooth, light.

Voluntary release

Strategies used to enhance voluntary release:

1. Hand weight bearing help the child to develop improved co contraction at the scapulo humeral area, the elbow, and the wrist.

2. Reaching activities that involve touching a desired target and holding that position for a few second be helpful.

3. Teaching the child to stabilize the arm against the body or on a surface prior to opening the hand be helpful compensatory strategies.

4. Facilitation of supination, abduction and external rotation make it easier for the child to use elbow extension and supination which allow for voluntary release with wrist extension.

5. Releasing into the container placed on the floor or at lower than the seat of the child chair teach the child to relax finger flexors.

6. As children develop more control with voluntary release therapist can gradually decrease object, weight, stability, and size of the area used for object placement.

General principles for developing hand manipulative skills

1. Provide somato-sensory stimuli: Typical activities used for sensory awareness may include: finding objects in beans, rice, or sand (graded finger movements are used to get the grains of rice or sand off the object), pulling pieces of clay off a ball of clay, pushing fingers into therapy putty or clay, stretching rubber bands around fingers.

2. Facilitate the use of intrinsic muscles in grasp and hand functions: pulling clay to facilitate use of intrinsic muscles, facilitate the use of metacarpophalangeal flexion with interphalangeal extension due to this pattern require use of intrinsic muscles. Emphasis on spheric grasp that use a combination of long flexor activity and intrinsic activity.

3. Encourage use of bilateral manipulation: infants manipulate objects between two hands, use of a surface on which to turn a puzzle piece and turning it within the hand.

Bilateral hand use training

In normal development babies develop gross symmetric bilateral skills such as (holding object with two hands, clapping, banging objects together), then stabilize objects with one hand while the other is manipulating (holding paper while coloring, holding a container while putting objects in), then manipulate objects with both hands simultaneously (stringing beads, tying a knot), the child may hold his hand on the paper while therapist draw a picture and ask child to guess what is being drawn, gradually the child is asked to do more with manipulated hand while using the stabilizing hand to maintain materials on the surface or in the grasp, padlock in which a key can be put into, markers with caps to put on, a box with a lid and objects to put inside the box, hold a cup with one hand while putting object in

with other hand, buttoning with both hands, tying a bow and doing craft project, fitting blocks together.

Reaching

1. By using water mat game, have sponged objects floating within, encourage reaching and touching to make the object move.
2. Busy boxes and rattles attached to playpen some of them are secured with table top with suction cup reaching is rewarded with sound movement.
3. All exercises for grasping used for reaching.

Results

Patients characteristics

Table 1 shows the demographic and clinical characteristics of all patients. There were 14 patients (46.7%) are boys and 16 patients (53.3%) as girls assessed by years there were 24 patients (80%) had mild degree spasticity, and 6 patients (20%) had moderated degree of spasticity on modified ashworth scale. Right hand dominance reported in 20 patients (66.7%), while 10 patients (33.3%) were left hand dominance. There was no significant difference between both groups in terms of age ($p=0.82$, sex 0.481), degree of spasticity ($p=0.379$) but significant difference in hand dominances ($p=0.02$).

Changes in hand grip strength

Mean test scores and standard deviations for both groups are shown in the table 2. The mean value of hand grip strength in both groups (assessed by kilo) at baseline measurement (pre-treatment) was insignificant ($p>0.05$).

Both groups had a significant improvement in hand grip strength post-treatment. The average improvement of hand grip strength tended to being highly significant in the study group (6.53 ± 1.408 versus 7.53 ± 1.68 , $p=0.001$) than in the control group (6.33 ± 1.29 versus 6.73 ± 1.83 , $p=0.028$). The percentage of improvement of hand grip strength were (15.31%) in the study group compared to the control group (6.3%).

Discussion

Altogether 15 hemiplegic C.P children were selected making up Group A and 15 hemiplegic C.P children were selected forming Group B. Demographic data showed that the mean age of the two groups were not significance difference ($p>0.01$). The hand function evaluation of Group (A) clearly illustrated mean differences in pre (6.53 ± 1.408) and post-treatment (7.53 ± 1.68) hand. There were differences in hand grip strength test scores between children in group (B) pre (6.33 ± 1.29) and post treatment (6.73 ± 1.38). This showed that they might have good

Variables	Control group n=15	Study group n=15	p-value
Age	5.13 ± 0.743	5.067 ± 0.798	0.82
Sex N (%)			
Boys	8 (53.3%)	6 (40%)	0.481
girls	7 (46.7%)	9 (60%)	
Degree of spasticity (%)			
Grade 1	11 (73.3%)	13 (86.7%)	0.379
Grade 1+	4 (26.7)	2 (14.3%)	
Hand dominance (%)			
Right	7 (46.7%)	13 (86.7%)	0.02
left	8 (53.3%)	2 (14.3%)	

Table 1: Patients' characteristics.

Hand grip strength	Study group Mean ± SD	Control group Mean ± SD	p-values (Between group)
Pre-treatment	6.53 ± 1.408	6.33 ± 1.29	0.688
Post-treatment	7.53 ± 1.68	6.73 ± 1.38	0.167
Improvement %	15.31%	6.3%	0.39
p-values (Within group)	0.001	0.028	

Table 2: The average test of hand grip strength in both groups.

motor function of the hand in terms of grip strength in the affected hand in both groups but more superiority for the group A. There are 35 muscles involved in movement of the forearm and hand, with many of these involved in gripping activities. During gripping activities, "the muscles of the flexor mechanism in the hand and forearm create grip strength while the extensors of the forearm stabilize the wrist. There are four major joints of the hand, carpometacarpal, intermetacarpal, mtacarpophalangeal, and interphalangeal joint, with 9 extrinsic muscles that cross the wrist and 10 intrinsic muscles with both of their attachments distal to the wrist. These muscles include the pronator radii teres, flexor carpi radialis, flexor carpi ulanris, flexor sublimis digitorum, and Palmaris longus on the extrinsic layer and the flexor profundus digitorum, flexor pollicis longus, pronator quadratus, flexor pollicis brevis, and abductor pollicis brevis on the intrinsic layer. Each of these muscles is active during gripping activities (Figure 2).

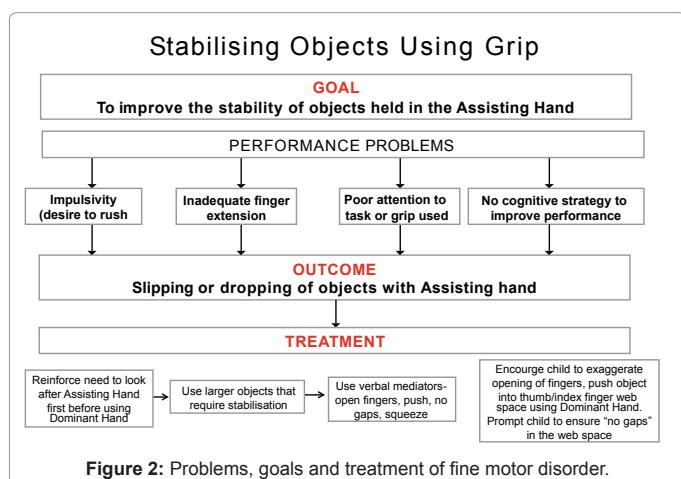
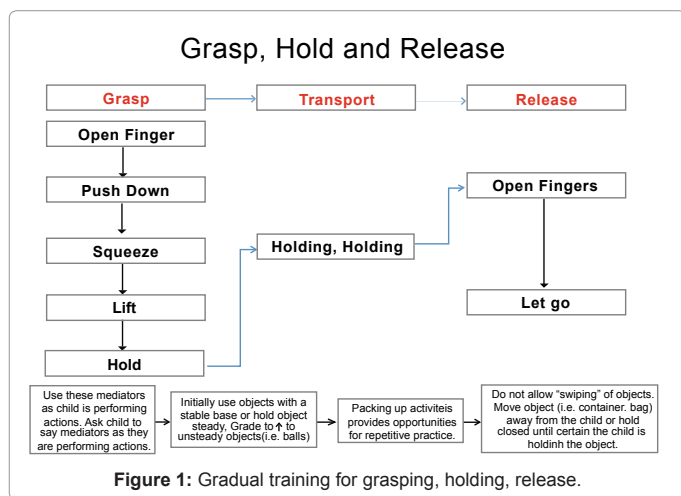
The characteristic structure of the hand is related to its function as a grasping tool. Grasping ability is made possible by the fact that the thumb can be opposed to the fingers. The fingers and the thumb act as a versatile pair of pliers. They need the palm of the hand as a flat base, on which the object grasped can be held. It can be concluded that the anatomy of the hand is more geared toward flexion than extension. Further proof lies in the strength of finger flexor vs. finger extensor musculature during isometric tasks. Their findings revealed the flexor mechanism of the fingers to be 62% stronger than the extensor mechanism A recent systematic review of all upper limb interventions in children with cerebral palsy found that occupational therapy in combination with physiotherapy program produced the largest treatment effect of all upper limb interventions on activity level outcome [12,13].

The underlying mechanism of hand function training

The more practice and repetition are key components of training which lead to more sensory input, feedback and permanent changes as new strategies and motor plan produced lead to learning a new skill or restore the lost skill. The nervous system provide the:

1. Sensory processing for perception of body orientation in space provided by visual, vestibular, and somato-sensory systems.
2. Sensory-motor integration essential for linking sensation to motor responses (centrally programmed postural adjustments that precede voluntary movement).
3. Mechanism of new motor strategy:

Information coming from periphery reached to the spinal cord through spinal nerves, information coming from head and neck reached to brainstem through cranial nerves. All the previous information reached to the thalamus to be sensitized then to the post-central gyrus to be localized. Perception, cognition, new sensory strategy will be produced by sensory areas which lead to increase of efficiency of synapses. After that information reach to cerebellum and



basal ganglion to be smoothening and prevention of excessive activity, then reach to pre-central gyrus to produce permanent changes and new motor behavior.

Which mean learning of new skill then formation of motor command via tracts to final common pathway (alpha and gamma MN) to perform new behavior of skills or reacquisition of skill (Figure 1). Despite the development of indices designed to assess the function of the hand's grip strength assessment remains the cornerstone of most longitudinal studies designed to show functional change in the hand.

Grip strength is frequently used in clinical trials and has been shown to be a sensitive indicator of disease activity. Grip strength is a composite measure and may be influenced by dysfunction in muscles, tendons, and any of the small joints of the hand and wrist [14].

Conclusion

Hand function training with traditional physiotherapy program should be considered in improvement of hand grip motor control and functional abilities of the hand in hemiplegic cerebral palsy children.

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