EFFECT OF SENSORIMOTOR STIMULATION ON MANUAL DEXTERITY AND HAND GRIP STRENGTH IN CHILDREN WITH DIPLEGIA: A RANDOMIZED CLINICAL TRIAL

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Abstract

Background: Children with diplegic cerebral palsy commonly exhibit sensory deficiencies in their hands in addition to motor problems. Impaired sensations negatively impact on acquisition of skilled movement which decreasing daily self-care activities and school activities. So the aim of the study was to assess the effect of sensorimotor stimulation on manual dexterity and handgrip strength in diplegic cerebral palsy children. **Subjects and methods:** Thirty diplegic cerebral palsy children were randomly allocated into two equal groups received successive three months intervention. Control group received designed occupational therapy program only, while study group received designed occupational therapy program in addition to sensory and perceptual stimulation program. Manual dexterity and grip strength were assessed by Bruinink-Oseretsky test and hand dynamometer, respectively. **Results:** data analyzed by paired t-testto compare the data within group and unpaired t-testto compare the data between both groups (study and control). There was a statistically significant improvement post-treatment in manual dexterity and handgrip strength in both groups and a statistically significant improvement in study group more than in control group. **Conclusion:** Sensorimotor stimulation had positive significant effect on manual dexterity (117.04%-46.82%) in study and control groups respectively and positive significant effect on hand grip strength (82.5%-38.91%)in the study and control groups respectively in children with diplegia.

Key words: diplegic cerebral palsy, sensorimotor, manual dexterity, grip strength.

Introduction:

Cerebral palsy (CP) is an umbrella term covering a group of non-progressive, but often changing, motor impairment syndromes secondary to lesions of the brain arising in early stages of its development,[1]leading to disability in movement and postural control. These symptoms are accompanied byproblems related to cognition, sensation, communication, and perception. [2]

Children with mild spastic diplegia may have relatively good hand function and fewer associated disabilities. In more severely affected children, upper limb function also may be compromised, depending upon the degree of spasticity and presence of contractures. Sensory loss, associated involuntary movements, and intellectual disability also may be present. Diplegic children have poor grasp-release and involuntary or associated movements. [3]

Dexterity is essential in many activities of daily living and has a significant effect on quality of life. [4] It is defined as the ability to manipulate objects quickly and efficiently using various prehensive patternsand it is important for independent function.[5]Manipulation includes co- ordination of different body segments that allow the hand for adapting to grasp different objects**.** [6]

Normal dexterity relies on a complex motor loop that includes the use of sensory information as a feed-forward and feedback series of mechanisms. For example, when an object is grasped, anticipatory control is used to predict the motor commands needed based on the object's physical properties, such as weight andsurface friction. [7]Internal representations of the object, as well as the mechanical characteristics of the limbs, allow a prediction of the consequences of voluntary movements, known as the feed-forward loop. [8]

Work activities as well as play, leisure and self-care activities require both grip strength and manual dexterity. Therefore, the grip strength is used extensively in the assessment of hand function.Because it is directly affected by the neural,muscular and skeletal systems, grip strength is used in theevaluation of patients with a large range of pathologiesthat impair the upper extremities, including musculoskeletal, neurological and congenital disorders.Hand grip strength measurement is important to identify the degree of disability and to determine efficacy of rehabilitation program.[9]

Children with CP commonly exhibit sensory deficiencies in their hands in addition to motor problems. [10]Sensory disturbances of central nervous system origin, such as poor two-point discrimination and a stereognosis, are common in all the spastic syndromes.[11]Sensory training has been proposed to be beneficial in improving function in conditions in which sensation is affected. [12]

Tactile dysfunction of hand can be treated with various tactile inputs training in discrimination of size, shape, and weight of objects and texture. It involves active and passive stimulation that place demands on receptors of skin to enhance normal sensitivity. [13]Wolpert and Ghahramaniwho studiedthe motor control were emphasized the importance of sensory feedback for movement. [14]

Improving hand functions becomes a high priority in the recovery of CP children which can lead to improvement in activities of daily living, and so enhancing their quality of life. Tactile stimulation has a beneficial effect on dexterity and manual ability of hand which may provide a basis for early sensory intervention and enhanced recovery of hand function. [15]

Thus, the aim of this study was to verify theeffect of sensorimotor stimulation on the manual dexterityand handgrip strength in children withdiaplegic cerebral palsy.

Materials and Methods:

Design of the study:

This study is double blinded Randomized controlled clinical trial with 2 parallel groups.

Participants:

Thirty diaplegic cerebral palsy childrenfrom both sexes participated in this study. They were recruited during the period from March 2018 till September 2018 from pediatric physical therapy centers and outpatient clinic at Monofiya Government, where the data was collected and the treatment was conducted. This study was approved by the research ethics committee of Physical Therapy College, Cairo University.

The participants were included in this study if their ages were ranged from four to ten years, they have impaired hand function as result of their neurological condition, they could understand and followed instructions, spasticity grades ranged from 1 to 1+ according to modified Ashworth scale [16], they had level II - III at manual ability classification system of hand. [17]They had level II-III in Gross motor function classification system. [18] Children could start reaching and were able to grasp hand dynamometer and they received regular physical therapy treatment. While, the participants were excluded if they had mental retardation, poor head or trunk control, recent neurological/orthopedic surgery of upper extremities or unhealed fracture, significant sensorimotor deficits, fixed deformities, significant Visual or auditory problems, recent botulinum toxic injection (within last 6 month) and epilepsy.

Ethical consideration:

All children's parents were given their informed (verbal or written) consent to have their children participate in the study.

Concealed Allocation:

After the baseline examination, patients with eligibility criteria were assigned with simple randomization to allocate in study or control group. Researcher not involved in either recruitmentor assessment of the patients used a computer-generated randomized table of numbers created prior to the start of data collection for Concealed allocation. Sequentially, individually numbered index cardscontaining the randomly assigned interventiongroup were folded and placedin opaque, sealed envelopes. The envelope was opened by a secondtherapist blinded to baseline examinationfindings. The treatment was preceded accordingto the group assignment on the day of theinitial examination.The children and their parents did not know their allocation in study or control group.

Measurement procedures:

The primary outcome measure was manual dexterity, with hand grip strength as secondary outcome. The evaluation was done before and after successive three months of treatment.

Assessment procedures:

A. Assessment tools for selection:

1-Modified Ashworth scale:The children were selected in this study hadslight increase in muscle tone, manifested by a catch and release or by minimal resistance at the end of the range of motion (grade1) or throughout the remainder (less than half) of the range of motion (grade 1+)[16].

2-Manual ability classification system of hand: The children were selected in the study handled most objects but with somewhat reduce quality and/or speed of achievement, handled objects with difficulty; needs help to prepare and/or modify activities.[17]

3-Gross motor function classification system:The children were selected in this study had walk indoors and outdoors, and climb stairs holding onto a rail, but experience limitations walking on uneven surfaces and inclines, or walk with an assistive mobility device. [18]

B- Assessment tools for evaluation:

1-Bruinink-Oseretsky test for motor proficiency:

The Bruinink-Oseretsky test for motor proficiency 2nd edition (BOT-2) is an individually administrated test that measures a wide array of fine and gross motor control skills in individual's ages 4 years through 21 years. It is designed to provide practitioners such as occupational therapists, developmental adaptive physical, educational teachers, and researchers, among others, with high reliability and validity.[19]It has moderate to strong inter-rater and test-retest reliabilities for complete form total motor composite and short form. [20]

In this study one subtest had been evaluated that was manual dexterity; this subtest used goal-directed activities that involve reaching, grasping and bimanual coordination with small objects.These Items include:pick up plastic pennies and placing them in to the box, stringing small blocks, sorting cards, placing pegs into a pegboard and making dots in circles

Emphasis is placed on: accuracy and timing of the items, so the child was asked to perform the task as quickly as possible. By including speed, the timed activities more precisely differentiate level of dexterity.[19]

2- Hand held dynamometer:

(The Jamar Hand Held Dynamometer"Serial Number: 30402264")

Hand grip strength is a standard parameter for hand function evaluation.Firstly, the participant's hand dominance was recorded, and then demonstrated how to hold the dynamometer. The child sat in comfortable chair with a back support and fixed arm rests, with rest their forearms on the arms of the chair keeping his/her feet flat on the floor, then he/she was asked to position his/her thumb round one side and his/her fingers around the other side of the handle. Shoulder adducted and in neutral rotation, elbow flexed at 90°, forearm in neutral position, wrist between 0-30° extension and 0-15° of ulnar deviation.After that, the examinee ensuredthat the red needle is in the "0" position by turning the dial, then encouraged the child to squeeze as long and as tightly as possible for the best result until the needle stopped rising. Finally, when the needle stopped rising, the measurement was recorded (the inner dial in lb.).Three trials were taken with 15-second inter-trial rest as sufficient to avoid fatigue; the mean of three trials was used in data analysis.[21]

Treatment procedures:

Intervention was given for both groups about one and half hour, three sessions per week for three successive months.Study group receiveddesigned occupational therapy program in addition to sensory and perceptual stimulation program, while control group receiveddesigned occupational therapy program only.

A. <u>Designed occupational therapy program</u>: It was applied to both study and control groups, it includes: therapeutic exercise andactivities to facilitate certain movements, and perception.

I. Therapeutic exercises:

Sustained manual stretching for long finger flexors, forearm supinator and wrist flexors was given for 30 seconds hold for each.

Strength training come in the form of functional design for upper limb (combing hair and hand to mouth as eating), wrist flexors and extensors and finger flexors strengthening with different sizes of hand gripper ball. The intensity of these exercises was increased by increasing the hold time and increasing the leverage.[15]

II. Activities to facilitate certain movements, and perception: It included activities to improving fine motor control, and promoting graphic skills. [22]

1- Improving fine motor control:it included the following activities.

- Rolled one-quarter inch balls of clay between the tips of thumb and the index and middle fingers (aimed to improve in hand manipulation skills as rotation and shifting)
- Made balls, rolled play dough into snakes, or created fun designs, quizzed roll of play dough with thumb and index finger (aimed to improve the pinch grasp as preparation to panther grasp).
- Cut roll of play dough to small pieces by tongue depressor to enhance the power grasp.
- Picked up small objects (e.g., colorful small balls) with a tweezers or tongs to transfer them, aimed to improve pinch grasp of hand.
- Pinched and sealed a Ziploc bag using the thumb opposing fingers of one hand while other hand supported the bag.
- Twisted and opened a small tube of toothpaste with the thumb and index and middle fingers to enhance the rotation of forearm to make a function.
- Moved a key from the palm to the fingertips of one hand then grasped by thumb and index fingers, aimed to enhance the in hand manipulation.
- Opened a clothespin put clip on shape that drawn in the card to enhance the pinch grasp.
- Stringed 2 beads on to a lace that enhance bimanual hand use and different grasp patterns.

2- Promoting graphic skills:

It includeddrew lines and copied shapes using sand trays, complete simple dot-to-dot pictures and imitate vertical stroke,and horizontal line.

B-<u>Sensory and perceptual stimulation program</u>:

It was applied to study group only. It included activities to enhance tactile stimulation,[15]according to Salker et al., the exercises were done in quite environment, withMotivation, Repetition (10 times) and Feedback on performance.

The exercises were started first with eyes open then with eyes closed.Stimulation was graded from gross to fine, rough to smooth, easy to difficult and the levels in tactile stimulation exercise were represented by the sequencing as follows[15]:

a. Identification training of the touch.
b. Identification training of various textures shapes and objects.
c. Discrimination training with first with same then with different texture, shapes objects (Matching tasks).

1- Identification training of the touch localization:

Touch stimulation and localization with eyes open and eyes closed. Eraser end of pencil was used, touch should be firm and maintained that was given from proximal to distal direction starting near the wrist and going down. The therapist was ask each child how many times did you touched and where.[15]

2- Texture stimulation:

Texture identification and discrimination with eyes open and eyes closed.Different textures were selected ranging from rough to smooth. Rough textures included, rough brush, rough stone, rough plastic, corrugated cardboard, course sandpaper, sack cloth whereas smooth textures included soft cloth, smooth stone, metal, glass. Individual textures first with rough and then moved on to smooth textures from proximal to distal direction.[15]

3- Identification and Discrimination of objects shape and size[15]:

- Identification and discrimination of the objects with eyes open and eyes closed.
- For proper object discrimination, tactile discrimination with texture, shape, sizes were required. Discrimination training was applied first with same then with different texture/ shapes/ size objects.

- Tactile discriminative training involved identification of geometric shapes by traced them on finger tips and other areas of hand.
- Tactile inputs included knowing of shape and size which were helped for tactile discrimination by dealing with spatial relationships.
- Basic different shapes was selected i.e. square, circle, rectangle, cylindrical which help to defined the edges of objects effectively and coincided with common objects of daily living.
- Different sizes of above shapes were given to each child.

4- Identification training of various objects weight:

Different weights of objects were given to each child e.g. different weight of balls, also different weight of cubes. Then the therapist was asked the child to differentiate objects weight.[15]

5- Identification and discrimination of objects of daily living:

Weight identification, identification and discrimination of objects of daily living with eyes open and eyes close. Actual Common objects were selected like Chocolate Big Bar, Bottle, Toothpaste, Coins, Buttons, Jam bottle, Pencil, Eraser, Spoon, Keys this objects were made to explored their shape, size and identification of them.[15]

6- Pick up, identification and discrimination of hidden objects:

Discrimination and identification of objects were done by putting the small objects into the bowls of rice and sand, then asked the child to pick up them without looking, and then identified object/ texture/ weight/ size.[15]

Home program:

It included push up exercises for upper limb and hand grip strength by soft strengthening ball. Advices were given to the child's parents for both groups to allow his/her child to do them regularly, two sets daily, ten times each one[22].

Data analysis:

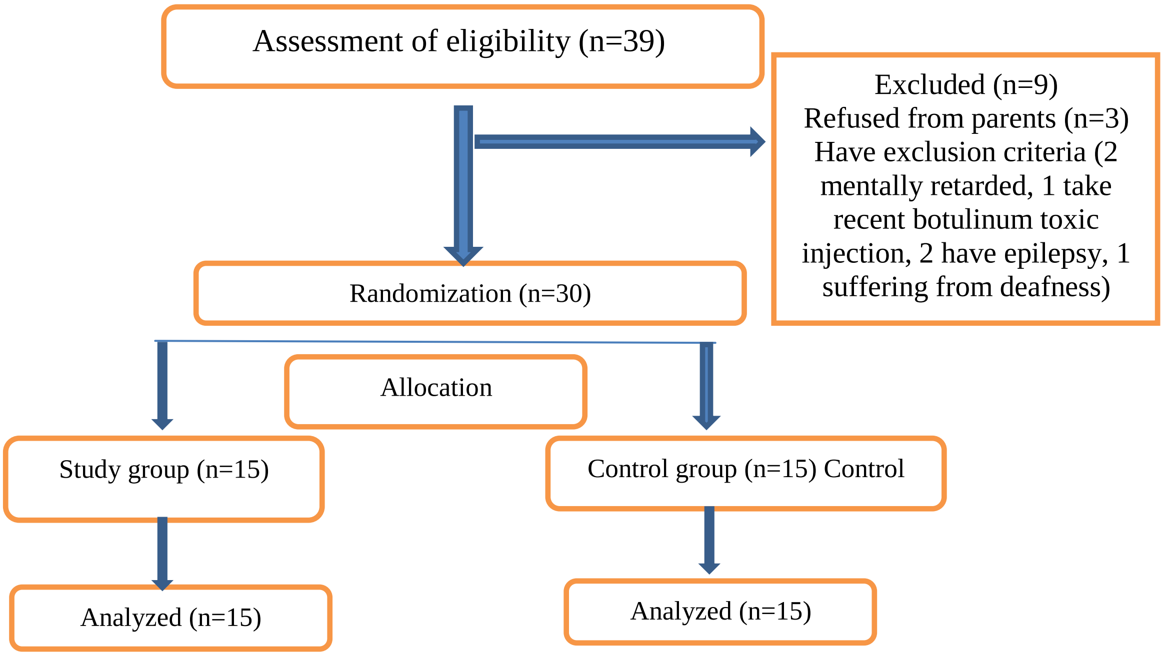
Reported data were analyzed using Statistical Package for Social Sciences (SPSS) computer program (version 17 windows) (Charles R Flint, New York, USA)**.** Individual paired t-tests (two tailed) for each group were done to determine the magnitude of changes within each groupto examine the effect of intervention on manual dexterity and hand grip strength in both study and control groups(pre- post).

Student un-paired t-tests, means and standard deviations were done tocomparing the general characteristics of the subjects between both groups, to comparing the means and standard deviations of manual dexterity and hand grip strength pre-treatment between groups andalso used to determine which group was superior when the interaction was significant (post- post).Chi-square was used to describe the distribution of gender and hand dominance in both groups. Descriptive analysis was obtained by using charts and histograms for each variable.

Results:

Thirty nine patients were screened for eligibility criteria. Thirty patients satisfied the eligibility criteria, agreed to participate, and were randomized to study group: n = 15 (mean ± SD age,7.785±1.804years; weight, 20.833 ±2.998kg: height, 123.267±10.80 cm), and control group: n = 15 (age, 27.633 ± 3.96 years; BMI, 28.85 ± 2.99; 14 males). The reasons for ineligibility are found in a flow diagram of patient recruitment and retention(Figure 1).

The distribution of gender and hand dominance in study group were (53.33% male, 46.67 % female,66.67% dominant right, 33.33% dominant left), while in control group were (46.67% male, 53.33% female,66.67% dominant right, 33.33% dominant left). There was no statistically significant difference (P= 1) between groups for both demographic (age, weight, height, gender and hand dominance) and measured variables at base line (Table 1-2).



Figure(1): A flow diagram of patient recruitment and retention

Table (1): The mean values of the age (years), weight (kg), height (cm) of the two groups (study and control).

		Groups						T-Test	
		Study Group (n=15)			Control Group (n=15)			T	P-value
Age (Years)	Range	4.08	-	10	4.08	-	9.33	-1.772	0.087
	Mean ±SD	7.785	±	1.804	6.760	±	1.331		
Weight (kg)	Range	17	-	26	15	-	28	0.513	0.612
	Mean ±SD	20.833	±	2.998	21.467	±	3.720		
Height (cm)	Range	106	-	141	110	-	161	1.297	0.205
	Mean ±SD	123.267	±	10.80	128.800	±	12.497		

SD: standard deviation p-value: probability value (non-significant)

Table (2):Hand dominance distribution and gender distribution within the two groups (study and control).

		Groups						Chi-Square	
		Study Group (n=15)		Control Group (n=15)		Total		X^2	P-value
Gender	Male	N	%	N	%	N	%		
		8	53.33	7	46.67	15	50.00	0.133	0.715
	Female	7	46.67	8	53.33	15	50.00		
Dominance	Right	10	66.67	10	66.67	20	66.67	0.001	1.000
	Left	5	33.33	5	33.33	10	33.33		

P- value: probability value (non- significant)

Unpaired t-test revealed that, there was no statistically significant difference (P= 1) regards the pre-treatment mean values ofmanual dexterity and hand grip strength of dominant hand in both groups.

Paired t-test revealed that, there was a statistical significant improvement (P<0.001), regards the post-treatment mean values ofmanual dexterity (BOT-2) in both groups (study and control) as shown in table (3). However, as regards post-treatment between the both groups (study and control), there was statistical significant improvementof mean values of manual dexterity (BOT-2) (p= 0.038), while the percentage of improvement was (117.04%) in favor to study group.

Table (3): Comparing the means values and standard deviations of manual dexterity (BOT-2) in both groups (study and control).

Manual dexterity (BOT-2)		Groups		T-Test	
		Study Group (n=15)	Control Group (n=15)	T	P-value
Pre	Mean ±SD	3.133 ± 1.846	3.133 ± 1.885	0.001	1.000
Post	Mean ±SD	6.800 ± 3.427	4.600 ± 1.882	-2.179	0.038*
Differences	Mean ±SD	3.667 ± 1.633	1.467 ± 0.834		
Paired Test	P-value	<0.001*	<0.001*		

(*) means: the p-value is significant.

Pairedt-test revealed that,there was a statistical significant improvement(P<0.001), regards the post-treatmentmean values of hand grip strength of dominant hand in both groups (study and control) asillustrated in figure (2).However, as regards post-treatmentbetween the both groups (study and control), there was statistical significant improvementof mean values of hand grip strength of dominant hand (p= 0.022), while the percentage of improvement was (82.5 %) in favor to study group

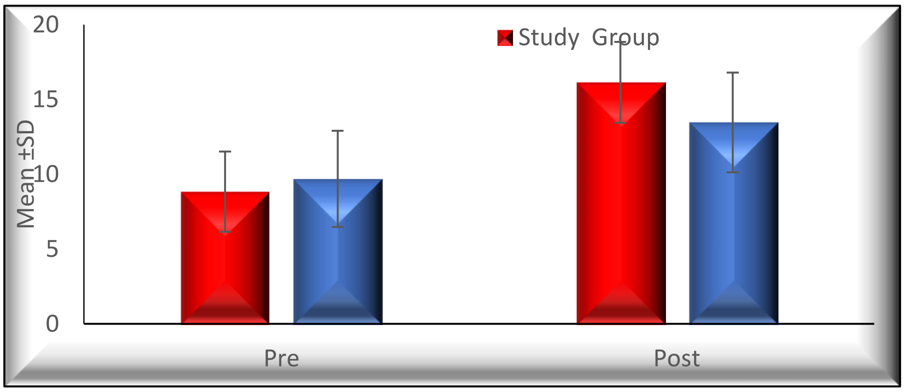


Figure (2): Comparing the mean value and standard deviation of hand grip strength of dominant hand in both groups (study and control).

DISCUSSION:

This study was conducted to examine the effect of sensorimotor stimulation on manual dexterity and hand grip strength in children with diaplegia.Results of this study suggested that sensory and perceptual stimulation program in addition to designed occupational therapy program have better effect on manual dexterity and hand grip strength in children with diaplegia than application of designed occupational therapy program alone.

The effect of sensory and perceptual stimulation program on manual dexterity:

There were a number of explanations for the improvement of manual dexterity in the study group. The grasp and manipulation were improved post-treatment could be attributed to sensory tactile information which conveys information regarding object texture, shape, size in the development of internal representation about an objects characteristic. These object characteristics help the child to scale the muscle force that exerted to lift the object, this scaling of force come prior to lifting the object depend on sensory and motor memory. [5] The accusation of the task post-treatment in study group was faster in performance than in control group that was related to sensory stimulation which made to orient to the object with proper shape, size and texture and discriminating them with other objects, this help to improve anticipatory control and improving hand functions. This finding is with agreement with the study done by **Gorden and Duff et al., (1999).**[23]

Enriched environment via sensory perception training in study group improve the manual dexterity and motor control corresponding to these cognitive and behavioral changes this based on, environmental enrichment induces anatomical and molecular changes in the brain. The former include neuro-, glio-, synapto- and angio-genesis, decreased cell death, and increases in receptor numbers, transmitter synthesis, dendritic length, and branching, and thickness of the cerebral cortexand increased levels of neurotransmitters, such as acetylcholine and noradrenaline, which promote neurogenesis and plasticity. [24] This come in agreement with **Kuoaet al., (2016),**[25] who reported that,the neuroplastic changes after tactile training are more likely to be associated with changes in the mental representations of the tactile stimuli in the somatosensory cortex.

At the end of the intervention the child's performance was improved in the speed and accuracy in manual dexterity test (BOT-2). The errors and falling of objects during the task performance also was decreased. This improvement could be attributed to the facilitated motor learning through the use of effective training strategies. This finding comes in the agreement with**Rosenkranz and Rothwell, (2012)**[26] **and Wong et al., (2012)**[27] who show that subjects who undergo additional sensory training carry out motor tasks with faster movement speed and less error.

The result of this study agree with **Salker et al., (2016)**[15] who reported that there was significant improvement in dexterity measure of children with hemiplegic cerebral palsy in study group who received conventional rehabilitation program and tactile stimulation exercises than control group who received conventional rehabilitation program.Also, the study of **Bumin and Kayihan, (2001)**[28] who explained thatSensory-perceptual-motor training was effective in study group of children with diplegic cerebral palsy than in the control group which was given only home programme.

On the other hand, the **Kuoa et al., (2016)**[25]showed that, there was no significant change in tactile registration and perception in CP children who receiving: 82 hours of intensive bimanual intervention plus eight hours of directed play with textured objects In the previous studies the possible explanation that they got different results may be due to eight hours of tactile training was insufficient to drive differential effects of perceptual learning between the two groups in children with CP, especially when cognitive capacity was required in perceptual learning.

Effect of designed occupational therapy program on manual dexterity:

Designed occupational therapy program which included strengthening exercise in the form of functional design for upper limb (combing hair and hand to mouth as eating), wrist flexors and extensors and finger flexors strengthening with different sizes of hand gripper ball that promote the improvement of strength through muscle fibers remodeling and neural adaptation by more recruitment of motor units to generate movement reflecting on muscle strength and hand performance. The most used methods to increase the capacity to generate strength in the patients of CP are the progressive resistance exercises, whose effects are noticeable improvement of the muscular performance and also on motor dexterity and conditioning. [29] Failure to increase motor unit firing rate during muscle contraction leading to weakness and loss of dexterity as typically seen in CP children**.** [5]

Furthermore, the improvement of objects identification and discrimination in study group was based on, active manipulation that obvious in occupational therapy program allowing successful object identification. Children with the worst baseline dexterity are also more likely to change from a passive to an active exploration mode after training, due to their improvements in motor function. [25]

The effect of sensory and perceptual stimulation program on hand grip strength:

In present study the improvement in hand grip pre and post-treatment in study group was attributed to, Two-point discrimination and grip-force adaptation indicates that fine discriminatory ability is related to the ability to differentiate the force output based on the object's texture. This comes in agreement with **Gorden and Duff, (1999)**[23] who reported that during lifts, internal representations of the object are used to preprogram grip lift task forces. Thus scaling of forces is performed prior to the lift and it is dependent on both sensory motor memory representation and current tactile information However, post-treatment the children preformed the task in better control and slipping of objects from there hand during task performance was decreased. This revealed to dynamically varying the level of muscle co-contraction may help in reducing tracking errors. [30]

Effect of designed occupational therapy program onhand grip strength:

In present study the Improvement in hand grip pre and post-treatment in control group could be attributed to strengthening exercise and fine motor task performance that included in intervention program. This comes in the agreement with **Blundell et al., (2003)**[31]who reported that the nature of the relationship between strength and function is considerable relevance to clinical practice that preformed in enjoyable manner for the child, other factors such as task-oriented skill training become more important for improving functional performance, The exercises in this study were designed to increase strength to the level required by the task rather than to maximize muscle force production.

Conclusion:

According to the result of present study, designed occupational therapy program in addition to sensory and perceptual stimulation program had better effect on gross and fine movement of the hand than designed occupational therapy program alone. Furthermore, sensorimotor stimulation had positive significant effect on manual dexterity and hand grip strength in children with diplegia.

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Conflict of Interest:

The Authors declare that there is no conflict of interest.

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