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ROBOT ENHANCED THERAPY FOR IMPAIRED UPPER EXTREMITIES FUNCTIONS IN HEMIPLEGIC CHILDREN

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Abstract

Objective: Studying the effect of Robot Enhanced Therapy on hemiplegic children. Thirty six spastic hemiplegic children were selected from comprehensive rehabilitation center in Najran, ranged in age from nine to twelve years old divided randomly into two matched groups. The control group received the selected program for correcting upper limb in addition to occupational therapy, while the study group received the same selected program for correcting upper limb pathomechanics in addition to robot enhanced therapy. Both groups received treatment for one hour three times weekly for three successive months. Maximum hand grip strength, shoulder range of motion and grasping age equivalent were measured for both groups before and after intervention. **Results:** There was significant improvement in all the measuring variables for both groups in favor for study group.

Conclusions: Robot assisted and computer enhanced hand therapy is an effective and promising method of hand function rehabilitation in hemiplegic children.

KEYWORDS: Hemiplegic Children. Occupational Therapy. Robotic Therapy.

1. INTRODUCTION

Hemiplegic cerebral palsied (CP) children account 30% of CP children**1**, characterized by affected arm and leg on one side of the body**2**. Hemiplegic children had difficulties in performing fine motor hand activities and had abnormal upper limb posturing during gait and in any activities required effort**3**. Combination of spasticity, weakness, and sensory and motor control deficits reduced functional abilities of the upper limb and resulting in children becoming one handed experts, the affected limb acting as a stabilizing or helper hand during everyday activities**4**.

Hand function deficits in hemiplegic children are a major cause of disability**5**. The child hold the arm in fixed postures, either extended or flexed during walking, and had clumsy, reciprocating, swinging arm movements or hold both arms flexed at the elbows. Affected children may extend their arms, pronate their hands, and clench their fists during running**6**.

Robot therapy has emerged in the last few decades to relearn patients with neurological injuries to motor tasks and improving their quality of life. Pediatric robotics is an arm orthosis with a spring mechanism for adjusting arm weight support, it supported functional therapy in children at the age of 4-12 years who had restricted function in their upper extremities**7**. Robotic therapy devices can automate the repetitive and strenuous aspects of conventional physical therapy and serve as scientific instruments for quantifying the recovery process**8**.

Exoskeleton robotized prosthesis designed to match and align their mechanical joints to human limb joints, in order to achieve articular decoupling and a good coverage of the whole arm range of motion (ROM) **9**. Robot assisted therapy was more effective in treatment of the upper extremity than, conventional therapy10. Robots are strong enough to complete movements when patients are completely impaired or when tone and spasticity act in opposition**11**.Robotic therapy encouraged motor recovery**12**, improved movement in completely impaired patient**13**, increased motor-plasticity during rehabilitation therapy**14, 15**.

The field of pediatric neurorehabilitation had rapidly evolved with the technological advancements. Rehabilitation robotics and computer-assisted systems complemented conventional physiotherapy and occupational therapy techniques, these systems appear promising in children. Despite large acceptance by the children and parents a few therapy systems have been evaluated in children, and there is lack of well-designed randomized controlled studies**16**.

2. MATERIAL AND METHODS

The study is a randomized controlled trial, the study procedures performed according to the ethical standards and after approval of the children families. The study performed over the period from March 2014 to November 2014.

Subjects**:** Thirty six spastic hemiplegic CP children of both genders, were selected from the Comprehensive rehabilitation center in Najran, The children were classified into blocks according to their severity. Then, with each block subject are randomly assigned to control and study groups to ensure that each treatment condition has equal proportion for control and study group Table (1). All children ranged in age from nine to twelve years old, had grade 1 or 1^{+} according to modified ashworth scale and grade II or III according to Manual Ability Classification Scale (MACS), All children can follow orders and had neither auditory nor visual disorders. Children were excluded if they had fixed contracture and deformity, surgical intervention as: muscle transfer and tenotomy, botulinum toxin injections, baclofen pump, spinal deformity, heart diseases, uncontrolled convulsions and involuntary movement.

Table 1: Description of block randomization.

MACS grades	Treatment	
	Control	Study
Grade II	9	9
Grade III	9	9

Materials: Calibrated Hand-Held Dynamometers (model 12-0256) Fig (1), calibrated Inclinometer (DUALER™ IQ) Fig (2) and Peabody developmental motor scale (PDMS-2) used for evaluation. ArmeoSpring Pediatric (HOCOMA): Instrumented arm orthosis with integrated am weight support occupied with pressure sensitive handgrip for functional grasping tasks and software library with functional exercises for motivating child interaction. The system mounted on a trolley for easy transfers of the ArmeoSpring, it had an electric lifting column for comfortable height adjustment (400 mm), it allowed instrumented degrees of freedom for shoulder flexion and extension, horizontal abduction and adduction, internal and external rotation, elbow flexion and extension, forearm pronation and supination, wrist flexion and extension. The length of the orthosis is adjustable between 14 to 22 cm for the upper arm and 15 to 30 cm for the forearm. It is equipped with a flat screen monitor (24 inch), integrated power supply and speakers. ArmeoSpring contains an extensive library of games like movement exercises supported by a virtual reality training environment that is motivating and informative, clearly displaying the functional task along with immediate performance feedback. The motivating and self-initiated exercises includes proximal and distal components, specifically related to: grasp and release, pronation and supination, wrist flexion and extension, reaching and retrieval function. The equipment detects even trace amounts of movement and function and facilitates intensive reach and grasp exercises at an early stage of therapy. The Armeocontrol Software allows managing of patient settings and individual therapy schedules. Occupational therapy tools for hand functional sessions.

Procedures:

Out comes measures: Maximum hand grip strength was measured by calibrated Electronic Hand Dynamometers, shoulder ROM (shoulder flexion and abduction) were measured by calibrated Inclinometer and fine motor skills was measured by PDMS-2 grasping section. Measurement performed for both groups before and after three months of interventions.

Treatment Intervention: The control group received the selected program for correcting upper limb pathomechanics including strengthening exercises, hand weight bearing, range of motion exercises and stretching for tight upper extremities muscles, in addition to occupational therapy program to improve hand functions, the occupational therapy program include training of hand function activities such as grasping, release, reaching, transfer, carrying and manipulation. The Study group received the same selected designed program for correction upper limb pathomechanics in addition to robot assisted and computer enhanced therapy by the Armeo Spring. The therapist adjust the electric lifting column according the child height during sitting and the length of the orthosis for upper arm and forearm to avoid compensartoy movement and to set the threee dimension workspace with adjusting amount of weight support, after introduing the child data to the apparatus the therapist select the childen appropiate program according to difficulty level, the computer used senes the joint angle to give visual movement feedback and track the therapy process Fig (3). The treatment will be conducted for both groups for one hour per session three times weekly for three successive months.

Data Analysis: Data Analysis: The statistical analyses were performed with the statistical package of social sciences (SPSS) version 20. Descriptive statistics (mean and standard deviation) were computed for all data. The paired t - test was applied for comparison within the group and the independent t - test was applied for pre and post treatment comparison between both groups.

3. RESULTS

There was no significant difference between both groups in age the mean age was 10.24±1.2 for the control group and 10.85±1.3 for the study group, ($p > 0.05$). There was no significant difference between both groups in gender, MACS and affected side the Chi-squared values was 0.22, 2 and 0.889 respectively ($p > 0.05$) as illustrated in table (2).

Table (2): Comparison between both groups in gender, MACS grades and affected side.

		Control Group	Study Group	X^2- value	P- value
Gender	Boys	10 (55.55%)	9 (50%)	0.22	0.63*
	Girls	8 (45.5%)	9 (50%)		
MACS	Grade II	6 (33.3%)	7 (38.89%)	2	0.157*
	Grade III	12 (66.6%)	11 (61.1%)		
Affected limb	RT	11(61.1%)	10 (55.5%)	0.889	0.346*
	LT	7(38.89%)	8 (45.5%)		

X^2: Chi-squared value ***: non-significant**

There was no significant difference between both groups before intervention in, hand grip strength, shoulder ROM and age equivalent of grasping ($p > 0.05$). Pre and post treatment comparison revealed significant difference in both groups in all measured variables ($p < 0.05$). post treatment comparison for both groups showed significant improvement for the study group ($p < 0.05$) as illustrated in table (3) and Fig (4,5,6,7).

Table (3): Comparison between both groups in all measured variables.

Variable	Time	Control group $\bar{X}$ ±SD	Study group $\bar{X}$ ±SD	P- value	S.D Error
Hand grip strength	Pre	9.42± 2.34	9.85± 2.41	0.89**	0.62
	Post	12.5±1.99	16.9 ±1.5	0.001*	0.72
	P- value	0.001*	0.001*		
	Standard error	0.63	0.39		
Shoulder abduction ROM	Pre	71±15	73±13	0.7**	0.158
	Post	82±11	91.5±9	0.001*	0.207
	P- value	0.001*	0.001*		
	Standard error	0.110	0.109		
Shoulder flexion ROM	Pre	63±6	61±8	0.18**	0.123
	Post	71±5	80±7	0.001*	0.105
	P- value	0.001*	0.001*		
	Standard error	0.149	0.121		
Age equivalent of grasping	Pre	12.64 ±2.7	13.57±2.59	0.54**	.64
	Post	19.78±3.2	25.14±4.1	0.001*	0.69
	P- value	0.001*	0.001*		
	Standard error	0.7	0.8		

$\bar{X}$ ±SD: mean± standard deviation p: level of significant *: significant **: non significant

4. DISCUSSION

Hemiplegic children suffered from upper extremities muscle weakness, spasticity, limited ROM, muscle tightness and abnormal mechanics hindering the children functional activities. The goal of habilitation in hemiplegic children is to improve independence in activities of daily living and reduce family care. Habilitation success depends on the intensity of therapy, repetition, and a goal-oriented and task-specific training program for achieving required executive motor function. The habilitation programs constructed to met the special needs of hemiplegic children. The traditional individual treatment sessions were expensive and limited resources hinder the achievement of optimal therapy and limit the dosages of habilitation sessions, the robotic therapy have been developed to overcome this problems and met the requirements of sensory motor learning.

The purpose of the current study was to investigate the effect of robot enhanced therapy on upper extremities function abilities in hemiplegic children concerning the proximal and distal control and hand function activities. Shoulder range of motion used as indicator of increase proximal motor control, hand grip strength used as indicators of distal motor control and the PDMS-2 used to measure function gain in upper extremities.

The study group showed significant improvement in hand grip strength, shoulder ROM and age equivalent after intervention this could be attributed to robot assisted therapy provides motivation and entertainment for children and revealed any remaining motor function abilities, children can benefit from highly intensive, repetitive, self-initiated movement therapy. The robots act as exoskeleton align upper extremities with anatomical axes providing weight support for affected extremities helping the child to overcome gravity and spasticity together with augmented feedback and enabling self-directed learning allowing the child to gain more proximal and distal motor control and increasing function ability. The robot provides any level of movement assistance and gravity compensation and improved shoulder ROM17. Hand exoskeleton rehabilitation robot improved hand grip strength18.

Robotic finger motivated patient with an engaging game environment that challenges individuated control of the fingers, automatically control assistance levels, and quantify finger individuation after stroke19. Robot assisted individuals with neurological disorders to independently drink from a glass20. Fasoli et al.21 demonstrated robot therapy improved quality of upper extremity test and the upper extremity Fugl-Meyer assessment scores22,23. Hesse et.al.24 demonstrated improvement on pronation, supination and wrist flexion and extension ROM in patients with stroke. Systematic review confirms the potential for robotic assisted devices to elicit improvements in proximal upper limb function25.

Improvement after intervention may be attributed to motivation and active participation of the children in an enriched environment play a fundamental role in the sensory motor learning as CP children were appear to be less motivated and had difficulty to remain motivated for prolonged motor habilitation program**26,27.** Research had shown that simply imagining movement of a limb activates the same regions of the motor cortex as actually performing the movement**28**. Mental practice alone can produce functional improvement**29.** Motivating training programs allowed prolonged rehabilitation and reduce the cost with high qualitatively and intensive level of training **30**. Augmented feedback during a vasomotor tracking task induced region-specific changes in frequency dependent power, interestingly, there was also increases in functional connectivity between cortical regions involved in the motor task**31**.

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 sensory processing for perception of body orientation in space provided by visual, vestibular, and somatosensory systems, sensory motor integration essential for linking sensation to motor responses. Robotic therapy foster somatosensory stimulation that induces brain plasticity**32**. Recent work has demonstrated that robot make changes in the electroencephalogram activity in neural cortical circuits and modulated contralateral alpha and beta frequency power in cortical areas**33.** Neuroplasticity is considered to be the underlying mechanism by progressive, challenging motor skill learning rather than merely repetitive motor tasks. Active voluntary motor skill learning leads to more prominent increases in activity in contralateral primary motor cortex, motor excitability recruitment curves, and intracortical facilitation**34**.

5. CONCLUSION

Robot assisted and computer enhanced hand therapy is an effective and promising method of hand function rehabilitation in hemiplegic children, it improved proximal and distal control in the upper extremities and hand function.

List of abbreviations:

MACS	Manual Ability Classification Scale
CP	Cerebral palsy
PDMS-2	Peabody developmental motor scale
ROM	Range of motion
SPSS	statistical package for social studies

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7. APPENDAGES

Fig (1): Electronic Hand-held Dynamometer

Fig (2): Inclinometer

Fig (3): Armeo Spring pediatric programs

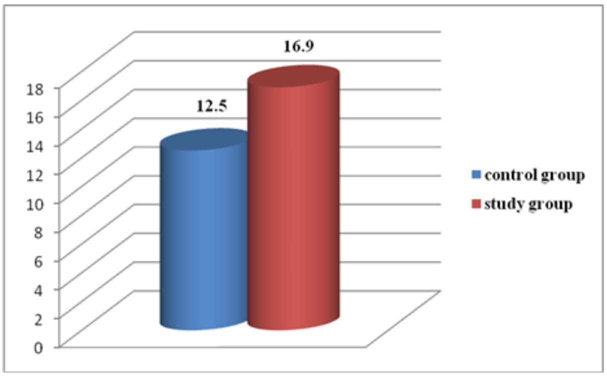

Fig (4): post treatment comparison between both groups in hand grip strength

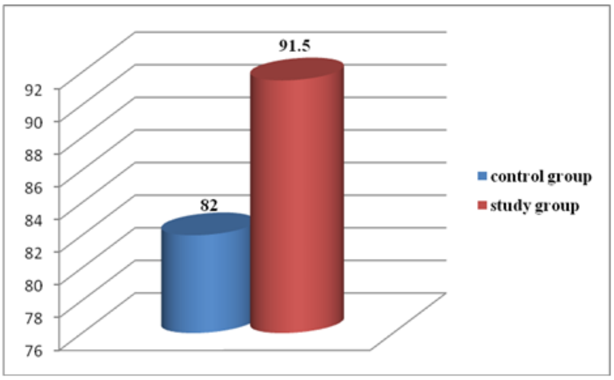

Fig (5): Post treatment comparison between both groups in shoulder abduction ROM.

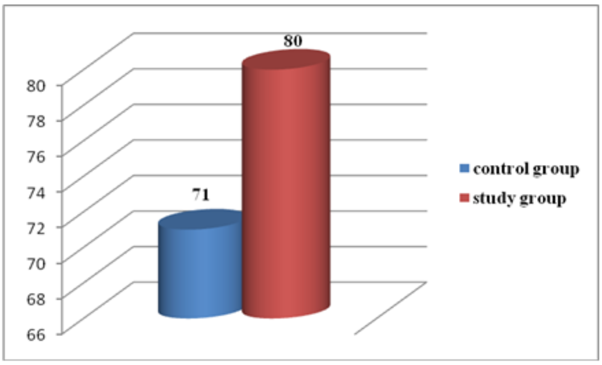

Fig (6): Post treatment comparison between both groups in shoulder flexion ROM.

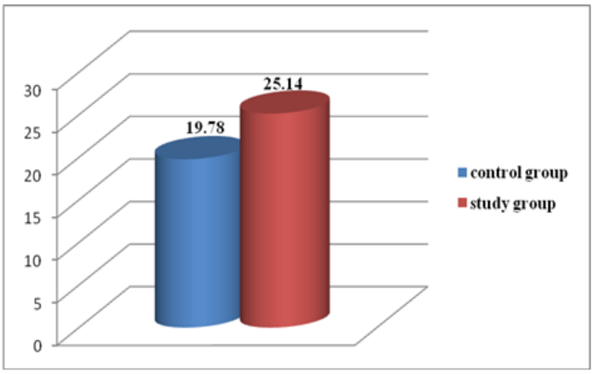

Fig (7): Post treatment comparison between both groups in grasping age equivalent.

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